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# THE DECEMBER SCIENTIFIC MONTHLY

Edited by

J. McKEEN CATTELL, F. R. MOULTON AND WARE CATTELL

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# NEW BOOKS OF SCIENTIFIC INTEREST

**Weather and the Ocean of Air.** W. H. WENSTROM. Illustrated. xviii + 484 pp. $4.50. 1942. Houghton Mifflin.

This book on the science of weather is directed expressly to the general reader. It describes in detail the air in which we live and the means and instruments through which it is explored. The new "air-mass-and-front" analysis is explained.

**Super-Electricity.** R. F. YATES. Illustrated. xviii + 165 pp. $2.00. September, 1942. D. Appleton-Century.

The author gives a brief account of the history of electronics and tells how one can become familiar with the subject at home or school. He then surveys the whole field of electronics as it exists to-day, with special emphasis on the possibilities of making it one's life work.

**Flush Production.** G. FORBES. Illustrated. xi + 253 pp. $2.75. October, 1942. Oklahoma.

In this history of oil development of the Gulf-Southwest, the author describes it through geology and exploration, discovery, drilling, production, refining, by-products, transportation, applications of science, conservation, social interpretation and folkways.

**Textbook of Histology.** 4th ed. MAXIMOW and BLOOM. Illustrated. xv + 695 pp. 1942. Saunders.

The purpose of this book is to provide students with a description of the minute structure of the human body and the morphologic evidences of its functions, introducing thereby as much of the data of physiology, pathology and experimental zoology as seem pertinent. The text is accompanied by photographs and diagrams.

**Du Pont, One Hundred and Forty Years.** W. S. Dutton. Illustrated. x + 396 pp. $3.00. 1942. Scribner.

This book is the biography of an industry—from the small gunpowder factory in Delaware in 1802 to the modern laboratory-factory that experiments with dyes, synthetic rubber, nylon, plastics, rayon, cellulose and the like, as well as with the implements of war.

**The Dilemma of Science.** W. M. AGAR. xvii + 140 pp. $2.00. October, 1942. Sheed and Ward.

A Catholic scientist attempts to present briefly the fundamental problems that lie back of science and to show their relationship with the views of the Catholic Church. He investigates the problem of knowledge and recent changes in the scientific view of nature.

**Speaking of Man.** M. F. GUYER. 321 pp. $3.50. October, 1942. Harper.

The author, professor of zoology at the University of Wisconsin, investigates man's place in nature and the relationship between modern science and human living. He believes that social behavior, human ideals, religion, war, international relations and the democratic experiment should be built on a basis of biological facts.

**The Mediterranean.** E. LUDWIG. Illustrated. xii + 635 pp. $3.75. August, 1942. Whittlesey.

This saga of a sea tells of its history from Odysseus to Mussolini. From the earliest communities of the East, the author traces the gradual expansion of the Mediterranean world, with its shifting tides of conquest and cultures and birth and deaths of whole civilizations.

**Near Horizons.** E. W. TEALE. Illustrated. xiv + 319 pp. $3.75. October, 1942. Dodd, Mead.

This is the informal story of some of the experiences of the author with the insects in his garden. Many of the adventures are supplemented with close-up photographs of the insects. Some of the chapters are: The House of Bubbles, Butterfly Battles, Ghost Bugs.

**Bird Migration.** A. L. THOMSON. Second ed. Illustrated. 192 pp. 6/–. 1942. Witherby (London).

This book gives a general account in non-technical language of bird migration—as to direction, season, method, speed, altitude, methods of study, ancient beliefs concerning it, etc. Modern theories on the causes and purposes of migration are discussed.

**Cuckoo Problems.** E. C. S. BAKER. Illustrated. xvi + 207 pp. 25/–. Witherby (London).

This book is an attempt to solve the many problems connected with the domestic economy of the Common Cuckoo and its relatives all over the world. The author studies the Cuckoo's eggs mainly from the viewpoint of its evolution.

**Man's Most Dangerous Myth: The Fallacy of Race.** M. F. A. MONTAGU. xi + 216 pp. $2.25. September, 1942. Columbia.

This volume is intended to disseminate the facts about "race" as science has come to know them. Some of the topics discussed are: origin of the concept of race, genetical theory of race, psychological factors, and race and war.

**The Status System of a Modern Community.** W. L. WARNER and P. S. LUNT. Illustrated. xx + 246 pp. $3.00. May 12, 1942. Yale.

This treatise is concerned with the various interrelations of the six social classes of a New England city. It takes up the structural pattern underlying cooperation among the several classes. About half the book consists of tabular matter.

**A Study of War.** 2 Vols. Q. WRIGHT. Illustrated. 1552 pp. $15.00. 1942. Chicago.

Volume I traces the history of warfare from hostilities among animals through primitive and historic civilizations to modern times. Volume II analyzes the causes of war and discusses the practical problem of preventing war. Statistical tables, maps and diagrams make graphic this extensive study.

THE SCIENTIFIC MONTHLY

DECEMBER, 1942

# WHAT ARE THE FITTEST?

## I. A MISCHIEVOUS FALLACY

By Dr. R. E. COKER

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*Are fitness and ruthlessness equivalent?* Man has long been distinguished from other animals by the development of language as one of the most important means of communication, and now he has devised such efficient methods of transmitting language that any sequence of words can be broadcast over the whole world to be received everywhere at almost the same instant. Never in the history of the world has there been such a plethora of words in print, in forums and committee meetings and everywhere all the time throughout the circumambient atmosphere. Words are intended to promote understanding and theoretically there should have ensued an equally unprecedented development of common understanding and cooperation among the peoples of the terrestrial globe. Yet there has probably never been a time when there prevailed greater divergence of thought among people or greater want of agreement in interpretation of words that are in daily use—ordinary words like *democracy, communism, freedom,* the *right to work* or *social order.*[1] It is a paradoxical situation: we have an unprecedented let-down of physical barriers to inter-communication and mutual understanding associated with a hitherto unknown state of conflict between nations and diversity of opinion concerning facts and principles of social relations. Instead of promoting general concert of thought and harmony of action, words seem to have contributed to confusion and to the instigation of human behavior worse than that of animals not blessed or cursed with the powers of language.

The trouble seems to be in the lack of words or in our capacity to ingest them, but rather in the capacity to *digest* the words we hear and read, that is to say, to use them intelligently, critically and honestly. We are perhaps becoming word-drunk.

In this article we consider a particular sequence of five words that once embodied a particular idea but that came to be used to convey another meaning, with consequences in behavior patterns that actually threaten the future of mankind. I refer to "the survival of the fittest," Herbert Spencer's translation of Charles Darwin's "Natural Selection." *Fittest* and *strongest* were never

[1] Merely for illustration, with no wish to be critical but rather with a truly inquiring mind, the writer would ask: Why in the minds of some is it a crime against democracy and a denial of freedom to require the payment of a dollar for the right to vote, and the very acme of democracy and sublimation of freedom to require a fee of twenty-five dollars, or much more, for the right to work or to vote on the conditions of work? Whatever may be right in either case, it seems only too obvious that we do not all use the same words with even approximately the same meanings.

intended to be synonymous terms in biology; or, to paraphrase, with apology for slang, fit'n'st and fight'n'st are not the same thing.

Naturally the question arises who is to say what these words mean and why may not the meanings attached to them by one group have just as much validity as those assigned by another? Well, those of us who are biologists are saved embarrassment in answering this question by the fact that those who misuse the term frequently say frankly, or imply, that they base their particular interpretation on its general biological interpretation. Since this alleged principle of perpetuation has recently been assuming greater and greater historical significance, biologists may fail in their responsibilities to the thinking world if they do not try to make clear to statesmen, historians and philosophers, to speakers and writers in general, either that they accept a common connotation or that the conventional use of the term "survival of the fittest" has not, and has never had, the sanction of those primarily occupied with analysis and interpretation of biological phenomena.[2] Biologists have indeed spoken out about this misconception, but, if we are to catch up with a wide-spread error, we may need to be more frequent and more vigorous in our educational effort with respect to a basic biological principle. Perhaps, in a way, while occupied with our own special business, we have let a false interpretation of biological thought go by default. It is indeed possible to give practical actuality to a false standard. You and I do not believe that successful banditry is a fair criterion of fitness to survive; but bandits can and frequently do make toleration or non-toleration of that mode of disorder a genuine test of survival. In this case the practice of banditry may properly be designated a pseudo-criterion and, under proper social conditions, it should affect the survival only of the few bandits, and that negatively.

It is well known that a very common lay interpretation of "natural selection" or "the survival of the fittest" is identified with the supposed principle of "tooth and claw" or with the alleged "law of the jungle" promulgated by those who never saw a jungle. We all know that this interpretation by whole nations, not indeed by all citizens of any nation (for no principle of action is ever recognized by all whose action it governs), but at least by a large and effectively influential portion of some nations, has now made the supposed rule of "the survival of the fittest" in threat and combat the basis of national policy. We know, moreover, that such a definition is accepted by a great number of otherwise competent non-biological thinkers as well as by some who do very little or only second-hand thinking. The not uncommon linkage of international war and the principle of natural selection was painfully exemplified recently by a radio speaker who, in concluding a somewhat dramatic narration of war news, exclaimed: "What a pity that Charles Darwin was ever born!" Thus exposing an appalling ignorance of Darwin!

*Origin of the term "survival of the fittest."* The law of the survival of the fittest, for, properly conceived, it is a *law* and not a theory at all, necessarily involves no such notions as those just mentioned; indeed it may even cry out against them. What Darwin was attempting to do, as is well known, was to develop an acceptable theory of the origin of species. What he actually did was to assemble a prodigious store of observational data—facts that any one might verify by the use of one's God-given senses—to lay these facts on the foundation of certain broad and indisputable premises, and thus to construct a factual edifice which any one might

[2] Even though a few biologists may have accepted the substitute definition of the term.

behold and employ in the search for an answer to the original question. Darwin himself was led to a particular sort of answer, this being the origin of species through *descent with modification*, with all plants and animals having universal kinship through common origin.

We are not concerned now with Darwin's answer but only with the premises and chiefly with a particular premise. The premises, which we have recently characterized as indisputable, are four. The first is the general principle of heredity—like begets like. No one disputes that. Of course, Darwin and his early followers could not know all that we now know about heredity or about variation or how they are so intimately related as to be merely different aspects of the same thing. We analyze heredity differently now in the light of knowledge gained since Darwin's time. We know that resemblances between parent and offspring are not every one to be regarded as falling within the technical category of inheritance; that is to say, as owing their origin to common descent. Yet the general idea of heredity is still admissibly sound: one does not have to be an evolutionist, a biologist or even a civilized man, to know that if you want a crop of corn you plant corn, not wheat; if you want hound dogs you breed hound dogs, not collies.

The second premise was described as "variation." This is a common word having more than one meaning, but here employed in one special sense. It is a fair presumption, however, that, when we speak of variation in connection with the origin of species, every one understands that we refer, not to variation in the sense of change, as when we speak of variable stars, but rather to differences between organisms, even between those having the closest kinship. No two are exactly alike.

As with heredity, so with variation in the special sense, we now, in the light of fuller information, analyze the differences between individuals differently from the way they were analyzed 75 years ago. We know that some of the differences are heritable in the sense that they have characterized ancestors and may be expected to reappear in the offspring regardless of differences in environment. We know that some features of structure or behavior can be accounted for through the conditions under which the particular animal has lived and may not be expected to reappear in the next generation, except as the progeny has similar environmental conditions, and that the same characters may just as likely appear in the progeny, appropriately environed, of ancestors that never displayed them because they had not had the environment necessary to bring out such qualities. We do not, of course, say that heredity has nothing to do with environment-induced characters, because we know it has. We observe, furthermore, that some variations have more significance than others for survival, for transmission and for contribution to evolutionary change. Nevertheless, no one denies the fact of variation or its general significance. To cite only a single example, every one knows, at least in a general way, about fingerprint identification and must realize that such a technique of identification would fail of its purpose if two men were exactly alike.

The third premise was that of *overproduction*. When we consider: that an oyster may liberate several million eggs in the course of its life, whereas, on the average, only one or a pair must ultimately survive; that a healthy oak in its long life may produce a million acorns; that some plant lice may have twelve generations a year at a hundred a generation, giving a total potential family from one plant louse of ten sextillion; when, with awareness of these and hosts of similar phenomena, we contrast the potentialities of infinite crowding with

the obvious fact that populations remain relatively unchanged throughout the centuries, we can not fail to recognize the general prevalence of overproduction. For every kind of animal or plant, potentialities vastly exceed actualities so far as populations are concerned.

We are thus led inevitably to the *fourth* premise. Since mass elimination must be and is a part of the order of nature, the small proportion of the young of any species that survive and propagate are, as a general but not absolute rule, those that have some advantage for survival and reproduction. To say that organisms possessing some advantage for survival and reproduction have no more chance of survival and self-perpetuation than those which are disadvantaged is to utter plain nonsense. An apology may be required for treating this question in so elementary a way, but one is continually surprised to find those who think of the survival of the fittest as a theory rather than an axiom. All that the "survival of the fittest" means, or was ever intended to mean in biological thought, is that those best fitted to survive under the prevailing conditions will, by and large, be those that survive and reproduce. You may not like it, but you can not change it. It is good biblical doctrine; "He that doeth these things shall not be moved"; "the way of the ungodly shall perish"; These "shall have everlasting life," those "shall be cast into outer darkness." In any religious, ethical or scientific system it is conceived that those who measure up to existing standards endure, those who do not are lost: there are criteria of survival, whether fixed or changing.

*Who are the fittest?* The real question arises *not* as to the principle of the survival of the fittest, but rather as to the qualities that make for fitness to survive, to populate the earth and to progress, that is to say, to grow progressively in the characteristics that have demonstrated fitness. Here we enter into the realm of opinion, and opinions will generally be based upon observation, inference, logic and, to be sure, in no little part, where the survival of man is involved, upon a reasonable faith; for it is another characteristic of man that he has ideals and faith, although the effect of his faith on his behavior in a group is most variable. With respect to mankind there may be diverse theories as to the conditions of survival, but it seems clear that any and all opinions fall necessarily into one of two opposing groups, and it may make a great difference what type of opinion any great group of people has; because man is again distinguished from lower animals by his notable capacity to modify his behavior or to have it modified under the influence of abstract opinions. It is really important, therefore, that actual or expressed principles of action be critically examined and appraised for their potentially good or bad effects on human behavior and on ultimate human welfare.

There is, for example, the expressed opinion that survival is best assured by aggressive combativeness carried even to the extreme or unscrupulous and merciless brutality. The behavior pattern governed by this theory of action has even been alleged to be a direct corollary of the theory of progressive evolution through natural selection. It might take us too far afield to go now into the facts and arguments which would establish the complete fallacy of such an allegation. Darwin needs no defense; but, so that the thoughtless ascription to him of such a conception of the conditions of survival and evolution may not go by default, I quote a few sentences from his book entitled "The Descent of Man." In this book he suggests (p. 79) that, had man been derived from "an animal possessing great size, strength and fe-

rocity," he "would not perhaps have become social; and this would most effectually have checked the acquirement of the higher mental qualities, such as sympathy, and the love of his fellows." A compensatory advantage for want of strength and speed he finds in "his social qualities, which lead him to give and receive aid from his fellow man." Again he says (p. 142, edition of Collier, 1900):

> The moral sense perhaps affords the best and highest distinction between man and the lower animals; but I need say nothing on this head, as I have so lately endeavored to show that the social instincts—the prime principle of man's moral constitution—with the aid of active intellectual powers and the effects of habit, naturally lead to the golden rule, "As ye would that men should do to you, do ye to them likewise;" and this lies at the foundation of morality.

Darwin did not overlook the fact that man has been socially cooperative in inter-tribal combats, or the fact that man has never attained any degree of perfection as a social organism, but rather "man still bears in his bodily frame the indelible stamp of his lowly origin," and, by implication, also in his social frame. According to Darwin, man owes his civilization in no small part to being social, cooperative and kindly. It may be that he was all wrong in this opinion, or that he overemphasized the social qualities, but at least it is nonsensical and libelous to ascribe to him a view that is the exact converse of the one he has so well expressed.

We have a theory that the necessity of survival makes imperative a habit of aggression, subjugation and exploitation, and we have what may be called the Darwinian view, or the biological contention, that man has attained his present state of development primarily through his social, cooperative and altruistic qualities. In describing the latter concept as "the biological view" it is not meant to imply that it is held exclusively by biologists, or that it was originated by them, but merely that it is the view which arises inevitably from the contemplation of biological phenomena by those directly concerned with the social behavior of animals. The broad and fundamental significance of cooperation in all kinds of animals is so large a subject that it would be impossible now to go into it extensively, but others of greater competence have already done so, as Kropotkin, Patten and Allee, and many others. There may be added here a suggestion of the fact that the great majority of animals never apparently set out to exterminate or subjugate their own kind. I wish that some proponents of the Germanic interpretation of "the survival of the fittest" would point out a few cases in nature where animals do this. The few groups of ants that have the practice of enslaving ants of different species offer no exception to the rule. The most successful of nature's experiments in production of a diversity of kinds and large populations is found among the insects and their relatives, which almost never engage in intra-specific warfare. The moths, the butterflies and the birds that come so frequently and often so delightfully to our attention offer conspicuous examples of survival in numbers while living without the urge to destroy or to subjugate others of their kind.

I wish we had space to consider the implications of the familiar struggle for existence, the combats for mates and the predator-prey relationships which, by the way, are usually mutually beneficial to the species involved. The reader may guess that this writer does not hold with a Chinese philosopher who characterized the lion as wicked because it fed upon other animals, but rather with the Hebrew philosopher who heard the "young lions roar after their prey and seek their meat from God." It is conceded that one so inclined may argue from the predator-prey relationships in

nature that there is justification for any people who feel it to be in the interest of their well-being to enslave others. One may make such an extension, but, in doing so, enters a realm of opinion or erects a personal social theory, and obviously does not follow an inevitable path of logic in the field of biological data. It is argument by analogy, and analogies are suspect.

On the one hand, then, there has been the theory of survival through aggression and the exercise of brute force, and, on the other, until recently at least, a wide-spread tendency to give lip service to the assumed superiority of the so-called higher qualities of cooperation, justice, mercy, honor and brotherly love. In contrast to the dogma that "might makes right" the Golden Rule has been taken as an ideal of perfection. No one has denied the value of this rule as a standard in human relations, although few may have practiced it with any high degree of fidelity.

Now with the choice between principles of cooperation and mutual helpfulness on the one hand and of selfish aggression on the other, there is little doubt as to what would be the answer of almost every one of us. Furthermore, I believe there is not the shadow of a doubt but that, in the long run, survival for groups of men will be the reward of those who have the greatest capacity for social organization, whose behavior best exemplifies the ideal of joint action for the common good rather than that of exploitation for the assumed good of a favored few, and who have the will and the virility to maintain an endurable order. I am not a historian but I am strongly inclined to the belief that history supports this conviction. The career of the human race is indeed a conspicuously chequered one. War for subjugation, exploitation, dishonesty, brutality and other illustrations of assumed disreputable behavior have always been more or less in the order of the day. But, at the same time, and at *all* times, there have been notable displays by individual and groups, of what we are pleased to call the *humane* qualities, finding effect in religion, in education, in legislation and sometimes in business or in just plain everyday human relations. Old-time books of history emphasized wars, robberies, exploitations and breakings of faith, with only incidental allusion to the social and moral phenomena characterizing the periods under consideration, and this sometimes in small-print appendixes to chapters; hence the aptness of the saying, "Happy is the people that has no history!" Such histories must have been wrong, for human societies could not at different times have progressed to such advanced stages as have repeatedly been realized had not the constructive forces generally predominated over the destructive ones.

Could great cultures have developed without some measure of dominance of energies directed toward justice and human welfare over energies directed at subjugation and exploitation? And have not declines of empires begun when the balance was reversed? Rome engaged in conquest but also in the improvement of human relations with the development of a practical science of jurisprudence that had no equal then or for a thousand years after. Its broad empire rested in part upon aggression, but also in part upon the fact that substantial numbers of people lived better under Roman rule and had some participation in the rule. It was not the loss of an urge to aggression or the decline of combat-effectiveness in the Praetorian Guard and other armies that undermined a great empire; it was rather the social disorganization of the whole state, the going wild of the spirit of survival through conquest, conquest of foreign peoples and of domestic rivals, that progressively weakened and destroyed a

great empire. An unending series of struggles that pitted group against group, leader against leader, army against army, not in argument and rivalry for moral and political support, but in the false tactics of "tooth and claw," sapped the power that had rested upon cooperation and a considerable measure of respect for order and justice. The British Empire has engaged in conquest, but unquestionably its power and its persistence have derived more from what it has given than from what it has taken. Remove from its contribution to history the ideals and the practices, imperfect of course, in respect to liberty and justice, and Britain would be as much an empire as Roumania or Bulgaria.

We anticipate the reply: "Granted, but had Rome and Britain not engaged in conquest they might have been as great empires as Denmark and Sweden." In referring to great societies that developed in the past it has not been meant to imply that, under the conditions of the times, their greatness stemmed from one cause alone, even if we may see one form of behavior contributing in greater measure to the rise and maintenance of imperial greatness and another taking ascendency in the wane. To me it seems a somewhat academic question whether war, pestilence, famine, infanticide and human sacrifice were once useful and necessary to the control of populations and the effective organization of society. The past is instructive but not a complete guide for the future. Conditions change and man, the most adaptable of all creatures, makes new and unexpected adjustments. If one's grandfather was a wealthy philanthropist of high social prestige, who was finally hanged for having been a horse thief, it does not follow that to attain wealth and prestige one should begin by being a horse thief. If I had the problem of restoring the Roman Empire I should think it important to distinguish carefully between the behavior which led to real greatness and that which contributed most to the fall, a distinction which Mussolini has not seemed careful to make.

The plain fact is that man is an extraordinarily imperfect social being. No one can take a candid objective look at the human species in comparison with others and not see in our own kind maladjustments to social life that have no real parallel in less highly socialized species, displays of "brutishness" that can not be matched in the behavior of lower animals. What animal species would find continued delight in cruelties to its own kind that serve no genuinely useful purpose? And human history abounds in such cruelties. What animal would deliberately choose the most prolonged and excruciatingly painful modes of torture and execution of their fellows as is recorded in the history of man, not in the past alone but in the very present? It is unfair to dumb brutes to describe some human actions as "brutish." Actions that characterize some types of men would more appropriately be called "human" than "brutal" or "beastly"; but we much prefer to call them "inhuman," thus saving our self-respect without insult to wild beasts. Doubtless the explanation of "man's inhumanity to man" is to be found in the fact that the possession of greater capacity for social control carries with it the greater capacity for social disorder. The higher the ascent the greater the possible fall. Our most vicious qualities may not, after all, have "the indelible stamp of man's lowly origin," but may rather be abnormal distortions of the higher qualities we have gained. If it is not a fallacy to say that *inhumanity* (in-*human*-ity) is ingrained in *human* beings, it is at least a contradiction in terms.

It is desirable to think of this distinction because it is apparent that some of man's vicious qualities, whether ingrained or not, armed as they may be

with modern weapons and means of destruction, may bring about a real degradation of human society. It is becoming increasingly necessary that the expressions of social maladjustment involving whole nations should be brought under control if such control is within the possibilities, and we shall consider that question farther on. Fortunately, as has been previously suggested, man has the capacity to change patterns of behavior under the influence of ideas and ideals and to control a minority of misfits, comprising those who, through mental or moral obliquity, or through misconception of the requirements for survival, have established pseudo-criteria to threaten human society as a whole. The real criterion for mankind is not that which any individual or group chooses to set up, but is rather the willingness of people in general to endure certain modes of behavior and the capacity for effective cooperation in maintenance of a tolerable world order. We preach and we respect toleration, but there develop conditions in which toleration becomes a fetish and a large and crushing measure of intolerance is the only salvation.

It should be apparent that under any free working of the alleged principle of survival of the strongest and most combative, there could be no survival. If the stated criterion were adhered to there would finally be one man, who could not live indefinitely. Quite obviously survival is assured only when there is agreement among a large number or a few on some policy of "live and let live." The ultimate criterion of survival would be a conception of social order or, at worst, an unconscious surrender to the necessity for such. At what stage in the condition of disorder the acceptance of the valid criterion takes effect, and the extent to which there is partial or complete subordination of the initial criterion (the pseudo-criterion), will vary with historical time, with place and with the state of development of human culture. Consequently, we have, under different conditions, a dominant tribe or federation of tribes, a Babylonian or Roman empire, a ruling class, ecclesiastic, patrician or proletariat, perhaps some future empire or federation, or conceivably we may yet have—who knows?—a human empire with rights and privileges not restricted to Germans, Japanese, British, Russians or Americans, not vested in priests, nobles, capitalists or laborers. The last concept seems idealistic beyond the fondest dreams of practicability, but, unless I mistake the signs, necessity will not be long in driving us farther in that direction than we have ever dreamed of going. Do we not need an "esprit du corps," that applies to a much larger "corps"—a spirit of loyalty to our kind conceived more broadly than we yet have conceived? The question is asked *realistically* rather than idealistically; for we may be *compelled* to face it, and very soon. In the continuation of this discussion, let us try to see what biological orientation, if any, can be found in a condition of social disruption which has no real precedent in human or biological history.

*(To be concluded)*

# INFANTILE PARALYSIS: THE INCITING AGENT AND SPECIFIC SERUM TREATMENT[1]

By Dr. EDWARD C. ROSENOW

PROFESSOR OF EXPERIMENTAL BACTERIOLOGY, MAYO FOUNDATION

THE deplorable nature of the handicap, paralysis, and the high death rate which often results from attacks of poliomyelitis that occur so frequently at the very onset of life have made this disease—aptly named infantile paralysis—perhaps the most dreaded of all the infectious diseases. Its prevention and cure have been one of the major problems of medical science ever since 1840 when it was first recognized as a distinct disease. The solution of this problem has been beset with difficulties inherent in the very nature of the disease and its causative agent. Poliomyelitis often occurs in sporadic and epidemic form far remote from other cases. The symptoms and signs at the onset of illness, before the deplorable paralysis occurs, are usually not sufficiently characteristic to be recognized readily, thus making early treatment difficult. The discovery in 1909 that the causative agent is a filtrable virus was the first great advance in the study of the problem. Bacteriologic studies which were yielding important results at that time were dropped forthwith because it was thought—and quite naturally—that any organism which could be seen and which could be cultivated on artificial culture media could no longer be considered as having significance in poliomyelitis. For seven years, 1909 to 1916, intensive studies on the mysterious virus, made under the most favorable auspices and by the greatest of scientists the world over, revealed important information as to the nature of this dread disease, the manner or route by which virus gains entrance into the body, and its specific localization in that part of the nervous system on which locomotion or function of muscles depends.

During this same period, studies of my own on the behavior of pneumococci and streptococci, the causes of different disease entities, yielded a mass of evidence indicating their mutability and their ever changing character when placed under diverse conditions. These basic observations have been corroborated since in essential respects by various investigators. As changes of size, shape and growth requirements were induced by subjecting these organisms to stress and strain in the test tube and in animals, under conditions in which relatively few organisms survived, marked changes of virulence and localizing power occurred. Moreover, streptococci that had been isolated freshly by special methods, and filtrates of these cultures, often produced extremely specific effects on intravenous injection into animals. This was especially true in experiments with the streptococci isolated from infected teeth and tonsils and from cerebrospinal fluid of patients in studies of a very painful disease—shingles or herpes zoster (acute posterior poliomyelitis). Herpes, or blistering of the skin in the involved area, associated with severe pain due to localization and lesions in the posterior or sensory roots of the spinal nerves and posterior columns of the spinal cord, was produced experimentally with the

[1] Names of authors and references to contributions in studies of poliomyelitis will not be given in this paper since they have been recorded elsewhere. Details and statistical figures of many experiments have been recorded in the medical literature and for the sake of brevity will be omitted, in large part, in this report. In all instances the number of experiments was sufficiently large to warrant the conclusions drawn.

living streptococcus and with filtrates of active cultures.

These and other similar observations led to the birth of a new concept regarding the nature of the inciting agent of poliomyelitis—that perhaps streptococci having specific affinity for the cells of the spinal cord which control locomotion, and other distinctive properties, might have causal relation to this disease, despite the fact that the inciting agent had been shown to pass through porcelain and other bacteriologic filters. Filtrability of inciting agents of disease and inability to demonstrate organisms in filtrates by the methods then available, I reasoned, did not imply necessarily that viruses were distinct entities wholly unrelated to bacteria, as was then and is still usually considered.

Opportunity was afforded me to put to the test this basic concept through the auspices of the Mayo Foundation and the New York Hospital. With mingled feelings of fear and high hopes, the opportunity was embraced during a small outbreak of poliomyelitis in Rochester, Minnesota, and during the large epidemic of poliomyelitis in New York City in 1916.

### Isolation and Demonstration of the Streptococcus

By special methods used successfully in a study of other diseases and described in the medical literature, a streptococcus was isolated from the nasopharynx or tonsils in each of seven cases of poliomyelitis that occurred in Rochester, and consistently from the nasopharynx and tonsils of many children who survived, and from emulsions and sometimes from filtrates of emulsions of brain and spinal cord of nineteen persons who had succumbed to poliomyelitis during the epidemic in New York. Excitement was high during the course of these studies as cultures continued to yield the streptococcus, always of the same type—often extremely pleomorphic, that is, large and exceedingly small forms sometimes in the same chain—and as, in turn, young cultures of the freshly isolated streptococcus yielded specific results in inoculated animals. Symptoms and lesions such as occurred in these studies were almost never encountered during the course of many similar experiments, before and since, after identical inoculations of streptococci isolated in studies of diseases other than poliomyelitis. Similar results were obtained by several other workers in consequence, but despite these striking results the bacteriologic study of this disease by adequate methods has not again been considered seriously by other investigators in this field. There is perhaps no better illustration in all medical science of the profound influence which point of view or concept has had on the solution of a problem than is given by the diverse studies on poliomyelitis.

Having consistently isolated a certain type of streptococcus in epidemic poliomyelitis as it occurred spontaneously in human beings, my co-workers and I immediately applied our methods to a bacteriologic study of experimental poliomyelitis in monkeys induced by the intracerebral inoculation of emulsions or filtrates of emulsions of spinal cord tissue of persons or monkeys that had succumbed to poliomyelitis. The same type of streptococcus was isolated in these studies. Moreover, the streptococcus, in the form chiefly of diplococci of varying size, was demonstrated consistently by us and by others in the lesions of the spinal cord of patients who had succumbed to poliomyelitis and of monkeys that had died from experimental poliomyelitis, and was proved absent in sites remote from lesions.

### Preparation and Use of the Poliomyelitis Antistreptococcic Serum

On the basis of these additional results and the absence of any highly effective method of treatment of poliomyelitis, we

immunized horses, at first with freshly isolated strains of the living streptococcus from patients, and later, after the epidemic had subsided, with strains freshly isolated from time to time during the period of immunization (seven months) from the spinal cords of monkeys that had succumbed to experimental poliomyelitis after inoculation of virus. At the end of the period of immunization the antistreptococcic serum, in extremely high dilutions, was found to agglutinate specifically the poliomyelitic type of streptococcus, which is an accepted measure of antibodies or of curative properties usually present in antiserums. Intravenous and intramuscular injections of the serum protected rabbits against inoculation of the streptococcus and protected monkeys against inoculation of poliomyelitic virus. The need for a curative serum was especially great then, as now, because even though convalescent poliomyelitis serum were effective it could not solve the problem, since the disease would have to continue to occur with its dire consequences to assure a supply of serum.

The first opportunity to use the antistreptococcic serum in the treatment of patients occurred in the summer of 1917 during an epidemic of poliomyelitis in Davenport, Iowa, and surrounding country and nearby towns. The results from its intravenous injection in the treatment of fifty-eight patients suffering from poliomyelitis were most gratifying. The findings, the amount of serum administered and the effects noted in each case treated were reported in detail at that time. It was truly encouraging to see patient after patient respond to the injection of this newly developed antiserum. Physicians, whose patients were seen in consultation and treated in their homes with the serum, were as impressed as we were. Diagnosis was made on the clinical history, physical examination and characteristic findings on immediate examination of the cerebrospinal fluid at the bedside. The serum was administered at once after the diagnosis was established.

The type of the disease in this epidemic was unusually severe. A high incidence of paralytic cases occurred. The mortality rate in the untreated group of twenty-three patients was 35 per cent. Of the fifty-eight patients receiving the serum, ten (17 per cent.) died. Excluding seven of the fatal cases in which the patients were practically moribund at the time of the first serum treatment, there were three deaths (6 per cent.)—in all of which the serum treatment was begun late—among fifty-one cases in which the serum could possibly have beneficial action. Paralysis did not develop in any of nineteen patients to whom serum treatment was given before its onset, and all nineteen patients recovered. Extension of paralysis rarely occurred among patients who recovered and in whom paralysis, often far advanced, was present at the time of the first serum treatment. Patients in the early stages of the dreaded bulbar type of the disease, with early difficulty in swallowing and breathing; patients having the ascending spinal type with almost complete flaccid paralysis of all extremities and with difficulty in breathing due to involvement of the nerve centers of the muscles of respiration, and even patients in the early stages of partial or complete coma often responded favorably to administration of the serum.

In order that the readers of this account may understand better the significance of what has been found, and that they may not forget the human side of science, I can not but report in some detail the happy result obtained in the case of one large family group on a farm in which two sisters, four and eight years of age, were stricken with this disease. Typical symptoms of poliomyelitis, consisting of nausea and vomiting, fever,

tremors and spasms of muscles and mental apathy, had begun two and three days, respectively, before I saw the patients. At the time of serum treatment the temperatures were 103.2 and 102° F., respectively. The tonsils were large, infected and congested, the throats were red, and the cervical lymph nodes were palpable. The pulse rates were extremely rapid. There was rigidity of the neck in both and flexion caused pain in the back. Both patients had fine and coarse tremors of the fingers and hands and were tremulous and ataxic. Physical examination of the patients and examination of the cerebrospinal fluid revealed findings typical of poliomyelitis.

Ten cubic centimeters of the poliomyelitis antistreptococcic serum was given intravenously to each child. Both were better the following day. Tremors and twitchings of muscles and the mental apathy had disappeared. There was no paralysis. The respective temperatures were lower and the rigidity of the neck and the knee reflexes were less marked. The injection of serum was repeated in each case and again the following day. The temperatures dropped promptly to normal and all symptoms disappeared. Both children recovered without paralysis, as shown in the photograph (Fig. 1). I have never seen two children of the same family who contracted poliomyelitis recover untreated without paralysis developing in at least one. Often the first one stricken succumbs or severe paralysis develops and the other recovers but usually not without some degree of paralysis. Sometimes both have succumbed to the disease. Similar gratifying results have since been obtained following serum treatment of two or more patients in family groups.

As has been indicated, the antiserum used intravenously with such striking results was prepared by inoculation of horses, at first with suspensions of streptococci freshly isolated from patients, and later with streptococci freshly isolated from the spinal cords of monkeys that had succumbed to poliomyelitis after inoculation of virus. In order to make more practical the preparation of antiserum, a method for the preservation of specific antigenic or immunizing properties of the streptococcus throughout the period of immunization of horses was searched for. It was found that by placing the freshly isolated streptococci in very dense suspensions in glycerin (2 parts) and 25 per cent. solution of sodium chloride (1 part) and keeping these in the refrigerator, antigenic specificity was preserved almost indefinitely. All subsequent batches of antistreptococcic serum used for treatment were prepared by diluting these dense suspensions as needed for injections throughout the period of immunization. The experimental and clinical results obtained by us from the intramuscular use of the antiserums prepared in this way, by physicians to whom the serum was sent gratis for study on request, and by physicians who have used the commercially prepared antiserum independently in different epidemics of poliomyelitis since, have been comparable with those obtained in 1917. A summary of results of these studies is given in Table 1.

The cases summarized in Table 1 represent published and as yet unpublished reports. I have studied the effects of the serum in treatment in altogether twenty different epidemics which have occurred since 1917 in different regions of the United States and in Cuba, in four institutional outbreaks and in many cases that have occurred in isolated family groups. The two most important consequences of this disease—death and residual paralysis—were found consistently lower, usually much lower, in the cases in which serum was used than in the control cases that occurred in the same epidemics.

TABLE 1

SUMMARY OF RESULTS FROM THE TREATMENT WITH POLIOMYELITIS ANTISTREPTOCOCCIC SERUM OF PATIENTS SUFFERING FROM ACUTE POLIOMYELITIS

| Cases studied by: | Condition of patient at time of first serum treatment | Cases | Deaths | | Cases* | Severe residual paralysis | |
|---|---|---|---|---|---|---|---|
| | | | Number | Per cent. | | Number | Per cent. |
| Rosenow and co-workers, and physicians to whom serum was sent on request | Before onset of paralysis ... | 487 | 16 | 3.3 | 460 | 9 | 2.0 |
| | After slight to moderate paralysis ..... | 696 | 42 | 6.0 | 621 | 20 | 3.2 |
| | After severe paralysis ..... | 771 | 134 | 17.4 | 635 | 150 | 23.6 |
| | Total ..... | 1,954 | 192 | 9.8 | 1,716 | 179 | 10.4 |
| | Controls, cases in which patients were not treated with serum, that occurred during the same epidemics | 711 | 176 | 24.8 | 540 | 178 | 33.0 |
| Other physicians, independently | Cases in which patients were treated with poliomyelitis antistreptococcic serum .. | 710 | 60 | 8.5 | | | |
| | Controls, cases in which patients were not treated with poliomyelitis antistreptococcic serum, that occurred in the same epidemics ..... | 2,026 | 407 | 20.1 | | | |
| Total cases in which patients were treated with poliomyelitis antistreptococcic serum ..... | | 2,664 | 252 | 9.5 | | | |
| Total control cases in which patients were not treated with poliomyelitis antistreptococci serum ..... | | 2,737 | 583 | 21.3 | | | |

* This group consists of those cases in which data as to end results were obtained.

As indicated in Table 1, the mortality rate in the groups receiving the serum in the early stages of the disease was reduced to an eighth and a fourth, and incidence of residual paralysis to about a sixteenth and a tenth, respectively, of the corresponding rates of patients who were not treated with serum. Even the patients that received the serum first after severe paralysis had occurred fared better than did the controls.

In most of the cases studied by me the patients were seen at home in consultation with the family physician. The serum was administered at once after the diagnosis had been established by spinal puncture and immediate examination of the cerebrospinal fluid, and not first after the patient had been subjected to fear and other stresses and after loss of precious time incident to hospitalization. The diagnostic skill of the family physician, as I have seen it, in recognizing and treating the unusual in illnesses as they occur in family units is truly commendable. The results reported to us by physicians to whom the serum was sent, and of those who reported results independently, were strikingly similar to ours. All who had opportunity to treat numbers of patients in early stages of the disease reported enthusiastically on the results obtained. The beneficial action noted at the bedside is indicated strikingly also in Table 1. Thus, of the total of 2,664 patients who were treated with the serum, 252 (9.5 per cent.) died, which is in sharp contrast to 583 deaths (21 per cent.) among 2,737 control cases that occurred in the same epidemics but in which the serum was not used.

Results from the use, under controlled conditions, of various batches of the poliomyelitis antistreptococcic serum in the treatment of experimental poliomyelitis in monkeys were also strikingly favorable. Thus, of a group of monkeys treated with different batches of serum after onset of paralysis, 46 per cent. died, whereas of a comparable group of control monkeys that had received inoculations of the same virus and that were

not treated with the serum 83 per cent. died.

To show that the beneficial effects obtained in treatment of poliomyelitis with the antistreptococcic serum were due to specific antibodies in the serum, virus was treated in the test tube with the freshly obtained immune horse serum, and as a control with normal horse serum, before it was inoculated into monkeys, in the hope that the virus might be rendered ineffective by the immune serum. Thus, death from poliomyelitis occurred in only 27 per cent. of monkeys inoculated with virus that had been treated with the immune horse serum, in contrast to a mortality rate of 79 per cent. of monkeys that had received the same virus but after identical treatment with normal horse serum.

The results from the therapeutic use of the serum in human beings and in monkeys, reported on from time to time in the medical literature and as summarized here, would have led, it is believed, to the general adoption of this specific serum treatment of poliomyelitis if the inciting agent had not been shown to be filtrable, and if all requirements showing causal relation of the streptococcus could then have been fulfilled. The latter, unfortunately, were not forthcoming until recently. It is, therefore, considered imperative to indicate briefly, step by step, the results obtained in further attempts to fulfill these requirements.

### Further Results Indicating Causal Relation of the Streptococcus

The streptococcus has been isolated consistently from various sources, such as nasopharynx, stool and cerebrospinal fluid of persons ill with spontaneous poliomyelitis, and from brain and spinal cord of those who had died, from nasopharynx of contacts and noncontacts within epidemic zones of poliomyelitis, and from cerebrospinal fluid, brain and spinal cord of monkeys ill with experimental poliomyelitis induced with virus. Control cultures made under identical conditions almost never yielded streptococci. By our methods, and never by those usually employed, the streptococcus was isolated from about a third of the filtrates of emulsions of spinal cord and brain of persons and monkeys that had succumbed during the acute stage of the disease. In short, it was possible to isolate this specific type of streptococcus from the very tissues and other materials in which virus has been demonstrated most often, whereas this was not possible from tissues shown to be free from virus.

It is a well-known fact that virus present in brain and spinal cord of persons and monkeys that have succumbed to poliomyelitis remains alive for a long time after preservation in 50 per cent. glycerin. Therefore, it was thought that if the virus and the streptococcus were related, the streptococcus should also survive such storage. Accordingly, cultures were made at intervals from, and monkeys were inoculated with, emulsions of brain and cord tissue that had been preserved in this way for a long time. It was found, during the course of many experiments, that the streptococcus was approximately as resistant as the virus. The incidence of isolations of the streptococcus and the successful production of poliomyelitis in monkeys with the virus, were highest soon after preservation and became progressively less, roughly in proportion to the duration of preservation, but isolations of streptococci and "virus takes" were successful for as long as four years in some instances.

### A Test for Susceptibility to Poliomyelitis

The need for a test of susceptibility was obvious and I reasoned that if the streptococcus really was of etiologic significance in poliomyelitis, then cutaneous

reactions eighteen to twenty-four hours after intradermal injection of the heat-killed streptococcus in appropriate amounts should be greater in susceptible than in immune persons. This was found to be strikingly true as large numbers of persons were tested with a suspension of dead poliomyelitic streptococci and with a similar suspension of arthritic streptococci used as a control.

Positive reactions were obtained in fifty-two (87 per cent.) of sixty persons tested at the onset of attacks of poliomyelitis, in contrast to twenty-eight (13 per cent.) of 209 persons tested during convalescence, or who had recovered from poliomyelitis two weeks to many years before. The incidence of reactors to the poliomyelitis test according to age groups among persons who had not had poliomyelitis was most interesting and was roughly proportional to the age incidence of the disease. Of 614 children from one to five years of age, 430 (70 per cent.) reacted; of 489 children from six to ten years of age, 364 (74 per cent.) reacted; of 445 children from eleven to fifteen years of age, 277 (62 per cent.) reacted, and in 1,125 persons sixteen years of age or more, 282 (25 per cent.) reacted. There was little variation of incidence of reactors (10 to 25 per cent.) to the arthritis antigen in the different groups.

Skin tests were also made on well persons of different age groups at a foundlings' home during an epidemic of severe poliomyelitis affecting chiefly infants and young children—truly infantile paralysis. On intradermal injection, the streptococcal suspension prepared from strains isolated from patients in this epidemic produced reactions in highest and significant incidence in infants and young children, the very age groups chiefly affected in this epidemic, whereas a comparable suspension of streptococci isolated from patients in an epidemic in which older children and young adults were chiefly affected produced reactions in highest and significant incidence in older children and young adults.

Moreover, in other studies it was found that adults who reacted markedly to the intradermal test reacted progressively less and became negative when the intradermal test was repeated after four weekly subcutaneous injections of a vaccine prepared with the freshly isolated strains of the streptococcus. In one study the serum was obtained from the blood of five persons before vaccination when the skin reactions were strongly positive, and after vaccination when the skin reactions had become negative. The serum obtained before vaccination did not, and that obtained after vaccination did, neutralize virus.

The male sex is known to be more susceptible to poliomyelitis than the female sex. In accord with this fact, among male students the incidence of reactors to the poliomyelitis intradermal test dropped from 23 per cent. during an epidemic of poliomyelitis to 14 per cent. six weeks later, whereas among female students the incidence dropped only from 19 to 17 per cent. There was no change in incidence of reactors among students tested as controls during the six weeks' period at a neighboring college in which no cases occurred.

### Protection of Monkeys with Streptococcic Vaccine

It was felt that if monkeys could be immunized with vaccines prepared with the poliomyelitic type of streptococcus so that they would be immune to intranasal inoculation of highly virulent poliomyelitic virus, there would be at hand another important link in the chain of evidence that the streptococcus is causative. This we were able to accomplish. Thus, only 26 per cent. of monkeys that had been immunized with living or heat-killed streptococci ob-

tained in studies of poliomyelitis succumbed to poliomyelitis, in contrast to 84 per cent. of a comparable group that had not been immunized and that received the same virus. Immunity was shown to last for at least one and a half years. In monkeys that received similar injections of vaccines prepared with streptococci obtained in studies of arthritis no protection was afforded. The basic requirements for the use of this type of vaccine for the immunization of persons were, therefore, fulfilled. However, since the number of cases of poliomyelitis that develop in epidemics is small in proportion to the total population, and at least 2,000 persons would have to be immunized during epidemics to protect one person, this would be impractical and almost impossible.

Monkeys thoroughly immunized with the poliomyelitic streptococcic vaccine remained well after inoculation of poliomyelitic virus whereas in monkeys only partially immunized, symptoms and lesions of encephalitis instead of poliomyelitis developed, illustrating the ability of virus to change or mutate under stress, as do pneumococci and streptococci, in order to survive. Most interestingly, the streptococci isolated from the inoculated poliomyelitic virus were shown to be poliomyelitic in type, whereas the streptococci isolated from the brain of the monkeys that were partially immunized and in which symptoms and lesions of encephalitis developed following inoculation of poliomyelitic virus, were found to be encephalitic in type.

### Diagnostic Tests for Poliomyelitis

The findings on examination of cerebrospinal fluid, while of great value in the diagnosis of poliomyelitis, are not always sufficiently characteristic to enable one to distinguish poliomyelitis from certain forms of encephalitis and tuberculous meningitis. Moreover, changes of cerebrospinal fluid from the normal do not occur until after penetration of the virus or streptococci into the nervous system. The need was therefore very great for a means of determining the type of infection at the very onset of suggestive symptoms, days before penetration by the virus or streptococcus of the nerve centers in the spinal cord. It should thus be possible to prevent paralysis and death of persons stricken, by therapeutic injections —at the very onset of symptoms—of a curative serum such as we have developed. Fortunately our studies yielded two relatively simple methods which make practical this possibility.

The precipitation test was made with the blood serums of persons and of monkeys by superimposing these serums on the poliomyelitis antistreptococcic serum in small test tubes and noting the occurrence of clouding at the interphase, or boundary between the two layers of serum, eighteen to twenty-four hours later. Clouding, or positive reaction, occurred in tests with fifty-six (85 per cent.) of sixty-six serums obtained from sixty-six patients during the acute stage (one to twenty-one days) of poliomyelitis, and in tests with only three serums (4.5 per cent.) of sixty-six persons who had been ill forty-two days or longer. The serums of a large series of monkeys obtained during the acute stage of poliomyelitis which developed after inoculation of virus, and the serums of a similar series of normal monkeys were subjected to the same precipitation test. Eighty-three per cent. of the serums of the poliomyelitis group and only 7 per cent. of the serums of the normal group gave a positive reaction with the poliomyelitis antistreptococcic serum.

It was found that during the acute stage of poliomyelitis the skin of patients gave an immediate (five to ten minutes) reaction at the site of intradermal injection of a minute amount of a 10 per cent. solution in saline of the

water-insoluble (euglobulin) fraction of the serum of horses that had been immunized with the streptococcus from poliomyelitis (Fig. 2), and that little or no reaction occurred following identical injections into well persons or persons ill with other diseases remote from epidemics of poliomyelitis. The idea at once occurred to me that this might prove to be the much needed and sought for, simple, early diagnostic test. Since first discovered in 1937, this test, checked with suitable controls, has proved to be highly specific as made on the skin of persons having poliomyelitis, and of well contacts and noncontacts, in altogether nineteen epidemics that occurred in widely separated cities or rural communities of the United States.[2] Fifteen independent observers who have applied the test have obtained similar results.

FIG. 1. SISTERS WHO RECOVERED WITHOUT PARALYSIS FROM POLIOMYELITIS AFTER ADMINISTRATION OF POLIOMYELITIS ANTISTREPTOCOCCIC SERUM IN EARLY STAGES OF THE DISEASE.

[2] Acknowledgment is here made to physicians, superintendents of hospitals, health officers, nurses and others who so generously cooperated in these studies.

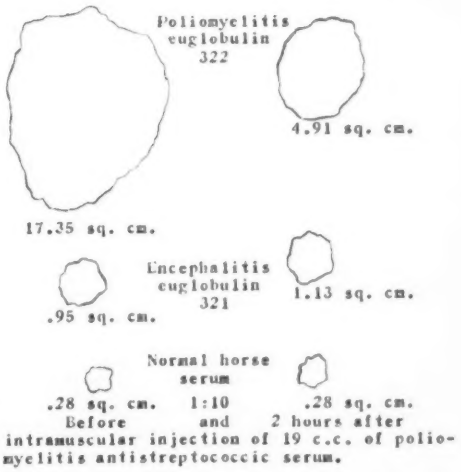


FIG. 2. TRACING OF ERYTHEMATOUS CUTANEOUS REACTIONS TO THE POLIOMYELITIS EUGLOBULIN AND CONTROLS, SHOWING MARKED REDUCTION IN REACTIVITY OF THE SKIN TO REINJECTION OF THE POLIOMYELITIS EUGLOBULIN FOLLOWING INTRAMUSCULAR INJECTION OF POLIOMYELITIS ANTISTREPTOCOCCIC SERUM IN A CASE OF ACUTE POLIOMYELITIS, SIXTH DAY. ($\times \frac{1}{4}$).

In ninety-two per cent. of 324 persons ill with poliomyelitis for from one to fourteen days cutaneous reactions, 5 sq. cm. or more in area, occurred to the poliomyelitis euglobulin. The average size in square centimeters of the erythematous reaction shown by patients during the acute stage of poliomyelitis was 8.7; by patients convalescing from poliomyelitis, 3.3; by well contacts, 4.2; by well persons within epidemic zones, 3.5, and by well persons remote from epidemics, 1.5.

A similar cutaneous reaction was found to occur in 90 per cent. of monkeys tested during attacks of experimental poliomyelitis produced with natural and laboratory virus (Fig. 3). No such reaction occurred in normal monkeys. Therapeutic injections of the poliomyelitis antistreptococcic serum into persons (Fig. 2) and monkeys during attacks of acute poliomyelitis caused the reactivity of both the skin and the blood serum to diminish or disappear

promptly as improvement of symptoms occurred.

In order to determine whether the cutaneous reaction obtained in persons and monkeys during attacks of poliomyelitis on intradermal injection of the poliomyelitis euglobulin was actually due to the presence of specific toxins of the streptococcus, monkeys were inoculated intracerebrally under ether anesthesia with large numbers of heat-killed streptococci obtained in studies of poliomyelitis and arthritis, respectively. In monkeys that had received the poliomyelitic streptococci flaccid paralysis developed associated with degeneration of motor cells in the spinal cord, and in those that had received the arthritic streptococci symptoms of arthritis and periarthritis developed. On skin testing these monkeys it was found that in those which received the poliomyelitic streptococci a specific cutaneous reaction occurred to the poliomyelitis euglobulin and in those inoculated with the arthritic streptococci the reaction was specific to the arthritis euglobulin. The monkeys that recovered after injection of the dead poliomyelitic streptococci resisted inoculation of virus, whereas those that recovered after injection of the dead arthritic streptococci succumbed to inoculation of virus.

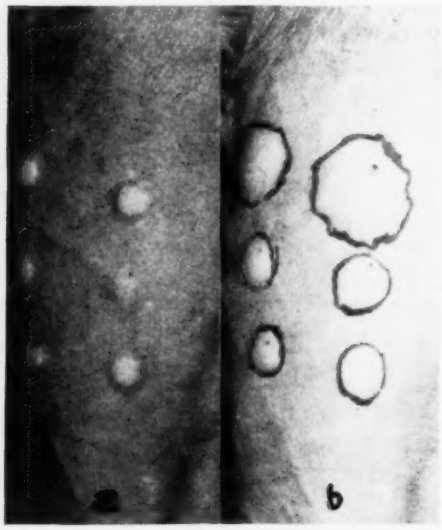


FIG. 3. CUTANEOUS REACTIONS IN A MACACUS RHESUS MONKEY ON THE THIRD DAY OF PARALYSIS FOLLOWING INOCULATION OF "NATURAL" VIRUS. (*a*) FIVE MINUTES AND (*b*) THIRTY MINUTES, AFTER INTRADERMAL INJECTION OF TWO BATCHES OF THE POLIOMYELITIS (*top row*), ENCEPHALITIS (*middle row*) AND ARTHRITIS (*bottom row*) EUGLOBULINS, RESPECTIVELY. NOTE POSITIVE REACTION TO POLIOMYELITIS EUGLOBULIN AND NEGATIVE REACTIONS TO ENCEPHALITIS AND ARTHRITIS EUGLOBULINS.

### Experimental Poliomyelitis after Inoculation of Virus Produced with the Streptococcus

Despite the important fact that flaccid paralysis and other symptoms of poliomyelitis have been produced consistently experimentally in animals by appropriate injections of the freshly isolated streptococcus, certain valid requirements were not fulfilled as proof of causal relation of the streptococcus. The symptoms after inoculation of the streptococcus into guinea-pigs, rabbits and monkeys developed within twenty-four to forty-eight hours instead of after a week or ten days, as occurs after inoculation of virus. If virulence or dosage was high, death from progressive paralysis occurred in from two to four days, before typical lesions developed, and if the virulence or dosage was low, recovery occurred soon after slight to moderate paralysis had developed. Moreover, the disease could not be reproduced in series in animals, as is possible with virus, by the inoculation of emulsions or filtrates of emulsions of the spinal cord.

The attempts to reproduce in the monkey all requirements with the streptococcus, as such, were numerous and without success throughout many years, but not without encouraging results. Finally, by the use of a medium consisting of infantile tissue—an autoclaved suspension of chick embryos—in which

acid reaction does not develop from growth of the streptococcus, we succeeded in producing filtrable virus from the streptococcus. This was accomplished with four strains of streptococci isolated in studies of poliomyelitis, from which the possible presence of virus was excluded, and with two strains of streptococci isolated from sources other than poliomyelitis, but which had virulence and other properties resembling those of the streptococcus from poliomyelitis. Excitement was indeed high when on successive passage of experimental virus from monkey to monkey symptoms and lesions typical of poliomyelitis developed. After the experimentally produced virus strains were adapted to monkeys from repeated passages they resembled "natural" virus in filtrability and other essential respects, as determined during the course of many experiments. Monkeys that had recovered from attacks of poliomyelitis after inoculation of "natural" virus were found immune to inoculation of different experimental virus strains and their blood serum neutralized the experimental virus, or rendered it ineffective, under the same conditions as "natural" virus.

As a climax to these extensive studies, we succeeded in demonstrating microdiplococci, often in short chains, unstained, with the new scientific tool—the electron microscope (Fig. 4), and with the light microscope after special staining (Fig. 5), in filtrates of "natural" and the experimentally produced virus, and in filtrates of old cultures in the chick embryo medium in which virus had developed from the streptococcus. It was estimated that 1 c.c. of filtrate contained as many as 400,000,000 microdiplococci and that some of these approximated the postulated size of the virus particle.

The streptococci as seen in cultures, cerebrospinal fluid and lesions, and the microdiplococci as seen in filtrates of

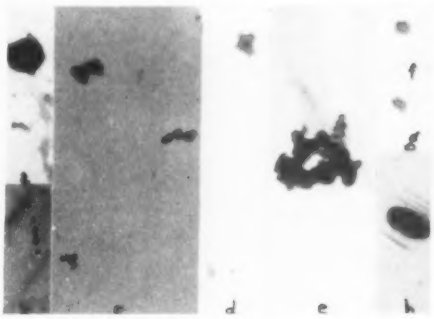

FIG. 4. LARGE AND SMALL COCCI

OVOIDS AND DIPLOCOCCI, SINGLE, IN CIRCLE AND IN SHORT CHAINS, RESEMBLING MICRO-ORGANISMS; REVEALED BY THE ELECTRON MICROSCOPE IN FILTRATES OF EMULSIONS OF THE SPINAL CORD OF A MONKEY THAT HAD SUCCUMBED TO "NATURAL" POLIOMYELITIC VIRUS. (UNSTAINED, 11,400).

virus, show similar variations in size, shape and grouping and are similar antigenically, but are very different in their growth requirements. While our mediums have often sufficed for the isolation of the streptococcus phase from cerebrospinal fluid, from emulsions of spinal cord and other material containing virus, and even from filtrates in which only microdiplococci are seen, they do not suffice to grow or isolate the virus or microdiplococci as such. The living cells or other conditions supplied by the brain and spinal cord or other tissues of susceptible animals are necessary but as growth occurs of the virus—both "natural" and experimental—the streptococcal phase also appears, demonstrable, although often with difficulty, in cerebrospinal fluid as symptoms develop and in the lesions after death. The streptococcal form has been found highly antigenic and suitable for the preparation of preventive vaccines and curative antiserums. The changes of size of the streptococci from small to large (virus to streptococcus) and from large to small (streptococcus to virus) form without apparent change in antigenicity resemble the phenomenon of polymerization in which great altera-

tions of physical properties occur in certain substances without change of chemical constitution.

## Summary and Conclusions

Throughout the many years in which my studies on poliomyelitis have been continued, concepts and facts were followed which resulted from leads suggested by experimental methods of trial and error. Inherent or acquired specific properties of the streptococcus, and at first of other bacteria, on isolation from the original source and as manifested in inoculated animals were considered of primary importance.

In addition to suggestive evidence which had been at hand for so long, some of which has been corroborated and extended by other investigators, including the striking beneficial action, in treatment, of the immune serum prepared with the streptococcus, convincing evidence indicating a causal relation of the streptococcus to poliomyelitis and the virus has now been adduced. Filtrable virus has been produced experimentally from streptococci and with it poliomyelitis has been produced many times in Macacus rhesus monkeys in series in the same way as with "natural" virus. Monkeys that had recovered from poliomyelitis after inoculations of "natural" virus were found immune to inoculations of the experimental virus and their blood serum obtained during convalescence neutralized the experimental virus. Microdiplococci —some approximating the postulated size of the virus particle—have been demonstrated in filtrates of both "natural" and experimental virus and in filtrates of old cultures of the streptococcus in chick embryo medium, the medium in which virus developed.

The immune serum which we and others have prepared in horses with the streptococcus has been shown to have

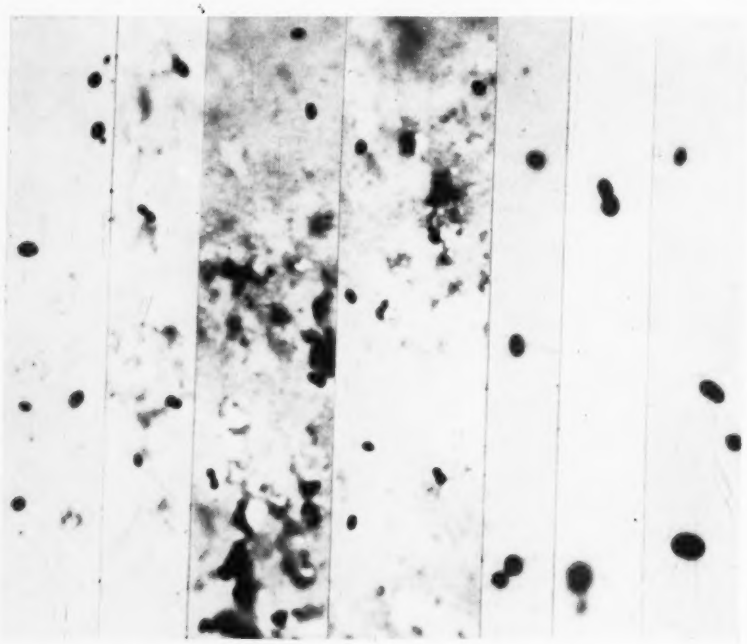

FIG. 5. COCCI, OVOIDS AND DIPLOCOCCI

SINGLE AND IN SHORT CHAINS, REVEALED BY THE ORDINARY LIGHT MICROSCOPE IN THE SAME FILTRATE REFERRED TO IN FIG. 4, AFTER SPECIAL STAINING. (×1,300).

diagnostic, preventive and curative action in treatment of poliomyelitis.

It is concluded that poliomyelitis is caused by a highly specific type of streptococcus and that what is now generally considered as virus is the small, filtrable microdiplococcus phase of the streptococcus. It is realized how contrary to current opinion these conclusions are, but the facts adduced permit no other interpretation. It is hoped that the methods and concepts which have led to these results, or better ones along similar lines, will be adopted generally, especially by those whose facilities and talents are far greater than mine, in order that the ravages of this most dreaded of diseases—infantile paralysis—may soon be brought under control.

# TOTEM POLES: A BY-PRODUCT OF THE FUR TRADE

By Dr. MARIUS BARBEAU

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THE belief has long been held that the totem poles of the North Pacific Coast are ancient, that they are a typical form of prehistoric art. Yet nothing is farther removed from the truth, if by totem pole we mean, as we should, a detached post consisting of a red cedar tree which was cut, hauled a certain distance—often a long distance—to an Indian village, where it was carved with symbolical figures usually of a heraldic character, and erected in the course of a feast in front of a chief's house to commemorate the passing of his predecessor and his own elevation to office. No totem pole, in so far as we know, ever came otherwise into existence, and this only in the restricted geographical areas, at first, of the Nass River and the Queen Charlotte Islands; next, of the southern Alaskan Coast, the Skeena and neighborhood; and later, of the coast farther south.

These heraldic memorials were derived from three contributing sources: (1) The earlier carved house posts prevailing over a wider area extending southwards to the Fraser River; (2) small graveyard figures of people or animals such as were found all along the coast as far north as Bering and also in adjacent Siberia and Japan; and (3) miniature carvings of stone, ivory and wood which, occasionally recovered on the North Pacific Coast, show that at least some of the stylistic devices of the native carvers were older than the totem poles and presumably went back to Asiatic prototypes.

The Russians in Alaska failed to make any record of any such structure among the Tlingit of Alaska, and the early white navigators along the coast only seldom observed house frontals with carved figures through which there was a round mouth-like entrance. It is only after 1830, more precisely after 1850, that totem poles became a feature of the villages of the Haidas, the Tsimsyan and the southern Tlingit, and after 1890, that they appeared at Alert Bay among the Kwakiutl and among the Nootka on the west side of Vancouver Island. The art reached its apogee between 1860 and 1880, and among outlying tribes like the Gitksan of the upper Skeena, it thrived until after 1900. A few indifferent poles there have been erected in the past ten years, but the custom of thus commemorating the dead as a whole is no longer prevailing, and in most parts the old

totem poles have decayed, fallen down or have been destroyed. Those that were left at the beginning of the present century were a cause of wonder to observers, and some of them were collected for museums or transplanted into public parks. Legends about them grew apace, with the added nimbus of mystery and antiquity, which were due only to the carelessness of the collectors, who neglected

TOTEM POLES

AT KISGAGAS (LOWER BABINE RIVER) AND KISPAYAKS (ON MIDDLE SKEENA) SHOWING THE SHINGLE CREST—THE RIBBED LINES IN THE MIDDLE.

to get the information then easily available.

To emphasize the novelty of totem pole carving and single out the causes which, after 1830, promoted its growth, I will select a few illustrations showing its connection with the fur trade, more particularly with the North West Company and the Hudson's Bay Company.

One of the two upper Gitksan tribes, that of Kisgagas or Sea-Gull near the outlet of the Babine River on the Skeena 225 miles from the sea-coast, was not far removed from Fort St. James, the earliest fur trading post of the North West Company established in 1808 in the northern Rockies. And it seems that the company soon after built a subsidiary post at Bear Lake, under the direction of a Mr. Ross. A Tsetsaut party at that time raided the village of Kisgagas while most of the hunters were away, killed two men with the flint-lock musket in their possession —the first gun seen in the country—and returned home with a female captive, a niece of the head-chief whom they had killed. The young woman was rescued by the white people at Bear Lake and later sent back home. A retaliation party, under her guidance, proceeded to the Tsetsaut country, but decided to visit the white man's fort on the way. Here they had their first opportunity to see the white man and to marvel at his possessions and his strange ways; to them all this was nothing less than a supernatural experience. What impressed them most was the white man's dog, the palisade or fortification of the house, and the broad wagon road—so different from their faint forest trails. All three of these they decided to adopt as their own crests or emblems after they had reached home. Waiget, the head of one family, took upon himself White-Man's Dog or Mr. Ross' Dog (called Masselaws); Malulek, another chief, assumed Palisade as his own; and other participants shared other similar crests. They gave two big feasts in the course of the next two years, to which they invited representatives of other Gitksan tribes as guests. And they exhibited with pride their new acquisitions, which they later carved on their totem poles or built—the palisade in the form of a small fence—around them.

Another family lower down on the upper Skeena, that of Harhu of Kis-

*Schallerer*

TOTEM POLE IN KETCHIKAN PARK

SUPPOSEDLY REPRESENTING CAPTAIN COOK ON HIS SHIP. THE MODEL PRESUMABLY WAS CAPTAIN VANCOUVER, FIRST WHITE SAILOR SEEN IN THESE PARTS, WHO SURVEYED THE COAST IN 1793.

payaks, likewise acquired the Shingle crest (*Ran'arhgyeek*), obviously from the white man's device of that name, after an ancestor once had proceeded either to the trading post of Bear Lake or Fort St. James. And this Shingle emblem on a Kispayaks totem pole is still seen in the form of parallel lines sloping down on both sides of a central ridge cut deep in the cedar.

Not a few instances of similar origins are noticeable on the totem poles and house frontals of the coast, for instance, the white sailor at the helm of a ship at Bella Coola (a short distance north of Vancouver Island) now preserved at the National Museum of Canada; another sea pilot at the top of a tall pole at Cape Fox, southern Alaska; a sailing ship with a sailor on its deck on a pole recently transplanted to Ketchikan, Alaska, and erroneously stated to represent Captain Cook—it presumably was inspired by Vancouver, who made the first coast map; and the splendid Haida pole now standing in the same park at Ketchikan and showing three Russian priests in church vestments, one above the other, two cherubs with wings out-

KAIGANI-HAIDA TOTEM POLE

(*Left*) OF THE THREE GREEK ORTHODOX PRIESTS (RUSSIAN), THE CHERUB AND THE TWO EAGLES; WITH ANOTHER POLE AND BROKEN SECTIONS OF A POLE, NOW AT KETCHIKAN, ALASKA. THESE HAVE BEEN PAINTED RECENTLY.

spread and two Russian eagles. This pole is from Kasan, a Haida-Kaigani village of Prince of Wales Island; it was carved over sixty years ago and erected, during a potlatch which some old people still remember, for a native family that showed its partiality at the time for the Greek Catholic church of the Russians. Another Kasan pole with scroll fret-work was said by an old Indian woman to have been carved by her uncle, who wanted to represent on it a Greek Catholic church certificate in his own possession.

These emblems were at first foreign to the Indians and have remained, since their assumption, the exclusive property of a few families. The bulk of totem pole figures elsewhere is of a different kind; it symbolizes familiar animals, legends and natural phenomena. The animals most commonly represented are the eagle, raven, frog, finback whale or blackfish, grizzly bear, wolf and thunder bird. Others, less frequently used, are the owl, salmon, woodpecker, beaver, shark, starfish, mountain goat, puma, moon, stars and rainbow. In the last resort these symbols were property marks on the houses and household effects and ceremonial carvings of the owners. They were not pagan gods nor demons, as they are often supposed to be. They are comparable to the stylized figures in our heraldry, yet they usually illustrate myths or tribal traditions. They were never worshipped, and if they were held sacred, it is only because of their implications. They were like tombstones, and indeed some of the same crests were, in the past 50 years, carved out of stone or marble at Port Simpson or Vancouver by white craftsmen for the new graveyards of the Indians.

The legendary origin of many of these emblems was explained in traditional narratives that used to be recited in the winter festivals or potlatches. They are still remembered by the members of the older generation, in spite of the decay of tribal customs. They recount how the ancestors long ago met with tribulations and adventures; how they were harassed or rescued by spirits and monsters; how benevolent spirits appeared in visions and invested their "protégés" with

*Pruell*

TOTEM POLES AND HOUSES IN THE DESERTED HAIDA VILLAGE OF KASAN ON PRINCE OF WALES ISLAND, SOUTHERN ALASKA. NOTE FIGURE OF A WHITE MAN WITH A LONG COAT AND TOP HAT ON TOP OF THE POLE TO THE RIGHT.

charms; and how ancient warriors conquered their enemies in warfare. The carved illustrations of these stories served a definite purpose, besides those of commemoration and ownership; they made familiar the legends and recollections of the past to all in tribal life.

Soon after the death of a chief, his prospective heirs appointed his leading nephew to his post. His induction took place in the midst of a large number of invited guests, during elaborate festivals, where liberality was an outstanding feature. The name of the "uncle" passed on to his "nephew" and the erection of a totem pole crowned the event. Groups of related families mustered all the resources available to make the feast memorable, as their standing and influence depended exactly in their resources thus advantageously displayed. If power and wealth were the ruling factors in the life of the North Pacific Coast people, it is obvious that these were modern among them; they issued from repeated contacts with white seamen and traders, from the greed for trade goods and from a keenness and industry inborn among these natives, whose recent origin was Siberian or Mongolian.

The remarkable development of native technique and style in totem pole carving is largely confined to the period subsequent to 1830. It hinged upon European tools, the steel axe, the adze and the curved knife, which were traded off in large numbers to the natives from the days of the early circumnavigators, that is, after 1778. The lack of suitable tools, wealth and leisure in the prehistoric period precluded the elaboration of ambitious structures and displays. The benefits accrued from the fur trade at once stimulated local ambitions; they stirred up jealousies and rivalries, and incited incredible efforts for higher prestige and leadership. The only desire everywhere was to outdo the others in

POLE OF NEESTSAWL

AT ANGYADAE ON THE NASS RIVER. CARVED BY OYAI FOR NEESTSAWL, HEAD OF A RAVEN FAMILY. IT STOOD AS A MEMORIAL TO CHIEF ISAWIT. THIS POLE IS NOW AT THE ROYAL EDINBURGH MUSEUM, SCOTLAND.

ingenuity, wealth and the display of power. The totem pole came into fashion through the rise of these ambitions. It became the acknowledged way of showing one's own identity in terms of the commemoration of illustrious dead, the decoration of imposing houses and the grand implications of ancient imagery. The size of the pole and the beauty of its figures published abroad the fame of those it represented.

Feuds over the size of totem poles as a result broke out among the leaders within a Nass River village, after the Hudson's Bay Company had established its trading post on the lower Nass in 1831 and transferred it to Fort Simpson in 1833, and had founded Victoria in 1843.

The Haida poles as we know them in

BEAR AND WOLF TOTEM POLE
OF ANGYADAE ON THE NASS RIVER WHICH WAS ERECTED ABOUT FIFTY YEARS AGO.

our museums are all of the same advanced type and virtually of the same period—1840–1880—and presumably all from the hands of carvers that were contemporaries. Their style was largely the result of miniature argillite carvings made by the ingenious craftsmen for the benefit of an early tourist traffic with the sailors and traders. The poles were from ten to thirty years old when the Haidas became converts to Christianity and in consequence gave up their customs, cut down some of their poles and sold them to white people, about the year 1890 or afterwards. It is a common saying that the fine row of poles in one of their best-known towns had risen from the proceeds of an inglorious type of barter in Victoria. There is no evidence of totem poles among the Haidas antedating 1840 or 1850, though a few earlier and transitional ones had served to introduce the fashion.

If the influence of the white man, his machinery and tools, upon the growth of the native art and totem pole carving of the North Pacific Coast, goes back to the earliest days of the fur trade, it is chiefly after steady contacts had been established by the Hudson's Bay Company that progress attained impressive proportions. One of the earliest references of such influence was given us by the Honorable Judge Howay; namely, that of a seaman named Jefferson who, as early as 1795, lent some machinery to the Haidas, together with sailors to assist, for the erection of a carved pole.

HALIBUT–BEAVER POLE
AT GITIKS ON THE LOWER NASS RIVER. ONLY THE LOWER PART OF THE POLE IS SHOWN.

Some Nass River natives also welcomed outside assistance at an early date; that is, over 100 years ago; and we should not forget that the trench method for starting the raising of a tall pole is identical with that of the South Sea islanders; or that South Sea islanders—Kanakas or Hawaiians or Sandwich islanders—were fairly numerous on the North Pacific Coast, as a result of their early immigration for the service of seamen and the Hudson's Bay Company.

Definite examples of totem poles erected as a result of relations between officers of the Hudson's Bay and the natives are too extensive for full quotation here; yet these include some of the best and tallest samples of the art, in particular on the lower Nass River. I have recently retold elsewhere (*Queen's Quarterly*, Autumn, 1939) the story of how the native wife of Captain McNeil, first of Port Simpson and then of Victoria, had incurred the wrath of her former Indian husband on the lower Nass. As he had publicly ridiculed and shamed her in her absence for her infidelity, she retaliated with the help of her new husband and erected one of the finest poles on the river, that of Bear-Mother and Angyadae, which is now preserved in the Trocadero Museum of Paris. And for variety's sake, other instances may now be briefly given here which belong to the same Angyadae and Geetiks clusters, perhaps the most remarkable of all for their size and quality.

The size of totem poles until about 1860 had had no special significance in itself, except that their carving required more time, and their erection made heavier demands on ingenuity and the many invited helpers in attendance.

Ambitious to excel all other chiefs once the ball was started rolling, Sispegoot, chief of the Blackfish clan on the lower Nass, decided to put up the tallest pole on the Nass, and its name would be Fin-of-the-Blackfish: just the Fin—not the whole Blackfish—to drive home to the other chiefs the sense of their approaching defeat. As if to make matters worse, Sispegoot would not engage Hladerh, his rival of the Wolf clan, as his carver, although Hladerh was entitled to this function by a usage in this tribe; rather he would command the services of Oyai, the canyon totem pole carver who was known to be partly of Kanaka extraction, and whose Grizzly-Bear pole for Mrs. McNeil was such a fine piece of work. So Oyai instead of Hladerh was entrusted by Sispegoot with the enterprise of carving the tallest totem ever seen in the country. This was bound to arouse the wrath of

EAGLE'S NEST POLE
OF THE LOWER NASS, NOW IN THE ZOOLOGICAL GARDEN AT CHARLESBOURG, QUEBEC.

Hladerh, who was already known to be proud and vindictive. But Sispegoot would not be cautious, and he was impatient to take the center of the stage for himself and his followers. He was sure that he could improve on Mrs. McNeil's totem, who at best had become an outsider and spent most of her time away, at Victoria.

However, there is no room here to recount the episodes of this feud about totem poles and prestige, for they are lengthy and varied; they are like an epic. The quarrel, which led to bloodshed, has not yet been forgotten, after a lapse of seventy-five years and the downfall of tribal customs. In a word Hladerh, being the head-chief of the Wolves (Larhkeebu), would not allow the erection of any pole that exceeded his own in height. Sispegoot, the head-chief of the Finback-Whales, could afford to disregard his rival's jealousies. When his new pole was carved, over sixty years ago, the news went out that it would be the tallest in the village. In spite of Hladerh's repeated warnings, Sispegoot issued invitations for its erection; but he was shot and wounded by Hladerh as he passed in front of his house in a canoe. The festival was perforce postponed for a year. Meanwhile Hladerh managed, through a clever plot, to have Sispegoot murdered by one of his own subordinates, thus enforcing his own will. He later compelled another chief of his own phratry, much to his humiliation, to shorten his pole twice after it was erected; and he was effectively checked only when he tried to spread his rule to an upper Nass village abroad.

## MEETINGS OF SCIENTIFIC SOCIETIES IN WARTIME

A MEMORANDUM on the holding of meetings of scientific and learned societies in wartime has been prepared within the last few weeks by the Science Committee which is advisory to the National Resources Planning Board, and which is composed of members designated by the National Research Council, the American Council on Education, the American Council of Learned Societies, and the Social Science Research Council. In essence, this memorandum states that in the war period scientific societies have an important part to play in the national effort, and meetings of these societies should be so organized as to be in the best public interest. It suggests, therefore, that each society or association consider its relationship to the war effort, and plan the programs of its meetings so that the most effective contribution will be made. In so far as possible meetings should not be held in or near defense areas, especially the ports and cities of the Atlantic seaboard, and should be scheduled for such days of the week as to avoid week-end travel. Meetings should be distributed among different cities to avoid congestion at any one point or along routes of travel.

The committee emphasized that meetings not closely connected with the war effort should be postponed, and that attendance at all meetings should be confined to those whose presence or participation is believed to be useful. Finally, they pointed out that the above statements are based upon conditions of transportation that exist at the present time, and that changes in these conditions may take place and may necessitate radical changes in plans for meetings. The directors of the Optical Society of America are taking these suggestions into full consideration in laying their plans for future meetings.—*From an Editorial, Journal of the Optical Society of America, October, 1942.*

# GEOGRAPHIC ROLE OF THE EVERGLADES IN THE EARLY HISTORY OF FLORIDA

By Professor L. LEMAR STEPHAN

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EXPLORATION and settlement of the Everglades lagged behind that of Florida as a whole. References to the Everglades in journals of early explorers are conspicuous for their scarcity. When settlers succeeded explorers, they chose parts of Florida presenting fewer initial problems than those of a marshland. Men let their imaginations play with the idea of draining and utilizing the "Glades" for a half century after settlement was established in the rest of the state. So not until early in the twentieth century did successful drainage operations make the Everglades appear to many as a new frontier of opportunity, one of the last of many successive frontiers in the United States.

## A BARRIER TO EXPLORATION

Early explorers heard rumors of "the place of the big water," but De Soto's map (Fig. 1) does not show any body of water that could be Lake Okeechobee. "When Jacob LeMoyne made his map of Florida (Fig. 2) in 1560, or thereabouts, he placed a large lake in the middle of the peninsula and made this note beside it . . . 'So great is this lake that one bank cannot be seen from the other.'"[1] After this date geographies mentioned the lake. Lake Okeechobee was, nevertheless, regarded by some as legendary as late as the early nineteenth century. Colonel John Lee Williams, who had done considerable traveling in Florida, prepared a map omitting Lake Okeechobee. The very existence of the most conspicuous item in the Everglades landscape, a lake forty miles wide, was open to question three centuries after the discovery of Florida.

Of lands lying southward from Lake Okeechobee even less was known. In 1898 Hugh L. Willoughby wrote in "Across the Everglades, A Canoe Journey:"

> It may seem strange, in our days of Arctic and African exploration, for the general public to learn that in our very midst, as it were, in one of our Atlantic Coast States, we have a tract of land one hundred and thirty miles long and seventy miles wide that is as much unknown to the white man as the heart of Africa. This tract occupies the southern part of the State. It is bounded on the north by Lake Okeechobee, on the east by the pine land about six miles wide facing the Atlantic, on the south by the mangrove swamps facing the Bay of Florida and the Big Cypress Swamp which touches the land of the west coast.

Twenty years later the Everglades had

FIG. 1. MAP DRAWN BY DE SOTO OF THE FLORIDA PENINSULA. HERNANDO DE SOTO WAS THE SPANISH EXPLORER WHO DISCOVERED THE MISSISSIPPI IN 1541.

[1] Charles Ledyard Norton, "A Handbook of Florida," p. 269. New York: Longmans, Green and Company. 1891.

given way to penetration. Then Nevin O. Winter could in retrospect say:

> The Great American Desert, once so feared, the wild solitudes of the Rockies, and the snowy wastes of the Yukon yielded up their innermost secrets before accurate knowledge of the Everglades was extended to the world. Its mystery has been a part of our national inheritance.[2]

The Everglades possessed neither of the two characteristics which encourage exploration of an unknown area. A land easy of access may be visited casually and thus settled. A land offering quick riches provides sufficient incentive to attract the intrepid, regardless of difficulty of access. No "fortune in a day" induced men to penetrate the sawgrass-blocked water routes of this reed-swamp; therefore, for more than three centuries the Everglades raised an obstacle of pure inertia to the movements of man.

[2] Nevin O. Winter, "Florida, The Land of Enchantment," pp. 2–3. Boston: The Page Company. 1918.

### A Place of Refuge

"Inaccessible to all except those familiar with their treacherous paths and labyrinthine channels, swamps have always afforded a refuge for individuals and peoples. . . ."[3] No exception to this principle, the Everglades, throughout its history, has sheltered diverse refugees: pirates, runaway slaves, Indians, Confederates and recently various law-

[3] Ellen C. Semple, "Influences of Geographic Environment," p. 371. New York: Henry Holt and Company. 1911.

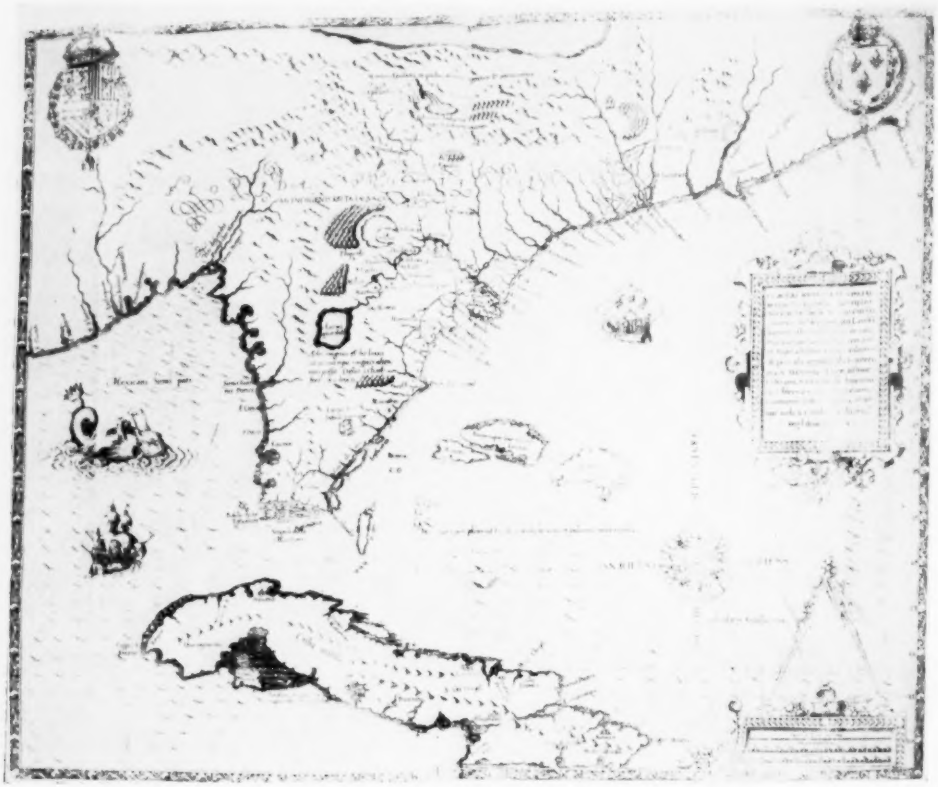


FIG. 2. MAP OF FLORIDA MADE BY JACOB LE MOYNE ABOUT 1560.

U.S.S.C.

MATURE SUGARCANE IN THE EVERGLADES

WHERE ONCE SAWGRASS GREW TO A HEIGHT OF TEN FEET, TO-DAY SEVERAL THOUSAND ACRES ARE IN FIELDS OF TALL SUGARCANE. THIS FIELD OF TYPICAL MATURE SUGARCANE IS ON THE HOLDINGS OF THE UNITED STATES SUGAR CORPORATION.

breakers, including bootleggers. Of these refugees, rumors and legend are many, facts fewer.

### Pirates

First in point of time to seek sanctuary in the Everglades were the pirates, who abounded for more than two centuries after the discovery of America. The loot appropriated from the Indians of Central and South America often was re-stolen several times before it reached Europe. "... pirates and buccaneers, who ventured along the Florida shores with their ships laden with rich booty, chased here by hostile pursuers . . . , would quickly disappear within the mysterious fastness of the Glades, and were absolutely lost to pursuit. Hence it is, that to this day there are innumerable tales of treasures existing in scuttled boats and of buried wealth in these winding streams."[4] There is no record of discovery of any buried pirate treasure.

[4] Winter, *op. cit.*, p. 296. See also p. vi.

### Slaves

During the first half of the nineteenth century, the prospect of a safe retreat afforded by the Everglades tempted many (usually Floridian) slaves to run away. Some joined the Indians; others banded together with their fellows and became more savage and dreaded than the Indians themselves. The Negroes paid tribute to the Indians in corn. The fact that Indians did harbor slaves, together with the fact that expeditions capturing escaped slaves frequently took slaves owned by Seminoles as well as runaways, caused friction between the whites and the Indians which resulted in the Seminole War of 1835.

### Seminole Indians

The Seminole Indians of Florida were a group of "runaways" from the Creeks of Georgia (probably mixing to some extent with the Colusa whom they dispossessed in south Florida, and Carib Indians who early rowed giant canoes

from their West Indian homes to south Florida[5]). The exodus was effected about 1750, after the Creeks had been for a generation allies of the British in their struggle against the Spanish. At the time of the rupture between the colonies and the mother-country, the British succeeded in implanting deep antagonism for Americans in the Seminoles. Attempts to reach an understanding between the United States and the Seminoles were thwarted for a half century by the persistence of mistrust.

The so-called First Seminole War was a direct offshoot of the British-American conflict of 1812–15. Andrew Jackson campaigned briefly in Florida in 1814 and again in 1818. The Second Seminole War resulted, in general, from the continued raids upon Indians for fugitive slaves, and, in particular, from the capture of the wife of Osceola, a prominent Indian leader, as a fugitive slave, although she had merely a trace of Negro blood and was already the mother of Osceola's four children. Relations with the whites had, furthermore, been

*John Newhouse*

WILLOW AND ELDER GROWTH

A TRANSITION ZONE ABOUT A MILE WIDE, BETWEEN THE SAWGRASS MARSH AND BETTER-DRAINED CUSTARD APPLE LANDS NEAR THE LAKE, CONSISTED OF DENSELY MATTED WILLOW AND ELDER TREES.

[5] Harriet G. Blackwell, "Our Most Beautiful Land Shell," *Natural History*, April, 1940, Vol. XLV, p. 217.

*John Newhouse*

SAWGRASS IN BLOOM

SAWGRASS, A HELIOPHYTE FOUR TO TEN FEET HIGH, DOMINATES THE UNCULTIVATED AREAS OF THE EVERGLADES MARSH OF FLORIDA.

strained by an attempt, in 1832, forcibly to remove the Indians to Western lands.

For seven years (1835–42) the war dragged on, costing the United States about $30,000,000 and many lives. The Indians retreated to the Everglades, where they were virtually secure from attack. "Many short scouting expeditions were made in the northern part of the Everglades, but when the troops got away from their base of supplies, the travel being slow and uncertain, they experienced terrible hunger and fatigue and were glad to turn to the coast."[6] Though a few of the Indian camping places were found and their crops destroyed, only once was the elusive Seminole defeated in battle. Finally,

On February 18, 1842, Colonel Worth reported that there were but three hundred Indians, including women and children, left in Florida. He said that it was impossible to secure these by force, and he, therefore, proposed that the number of troops in the territory be reduced. . . .[7]

[6] Hugh L. Willoughby, "Across the Everglades, A Canoe Journey," p. 19. Philadelphia: J. B. Lippincott Company. 1898.

[7] Caroline Mays Brevard, "A History of Florida from the Treaty of 1763 to Our Own Times," Vol. 1, pp. 162–163. Ed. James Alexander Robertson. 2 vols. Deland, Florida: The Florida Historical Society. 1924.

*John Newhouse*

CLEARING A ROADWAY

RIMMING THE SOUTH SHORE OF LAKE OKEECHOBEE WAS A BELT OF CUSTARD APPLE TREES AS MUCH AS A MILE AND A HALF DEEP.

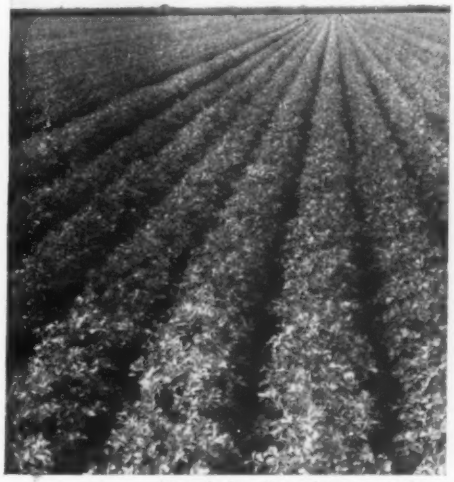
He reached a personal understanding with the Seminoles that so long as they let the whites alone, they should not be disturbed. This compact has been better kept by the Indians than by the whites.

Prior to the cessation of fighting, about five hundred Indians and their Negroes were persuaded to emigrate to Oklahoma. Later it was decided that the Indians remaining in south Florida should be granted a reservation. The lands assigned to the Indians extended from the mouth of the Peace Creek to the fork of its southern branch, thence to the head of Lake Istokpoga, thence down the Kissimmee to Lake Okeechobee, through the Everglades to the Shark River, thence along the coast to the starting point.

After peace was established, in 1842, federal troops proceeded to explore southern Florida and to make roads. In 1852 a small steamboat and nine metallic boats were provided for use on Lake Okeechobee and elsewhere in the vicinity.

In 1855 came the "incident" inevitable when white men seek to open up an Indian domain for civilization. An exploring party under Lieutenant Hartsoff destroyed banana trees and shot pumpkins in the garden of Chief Billy Bowlegs. The next day Hartsoff's party was attacked and soon afterwards raids were made on the homes of white settlers near the coast. State troops were called out and served nearly three years before order was restored.

The superintendent of the Western Seminoles, with two assistants and forty-six Indians, arrived in Florida January, 1858, and persuaded Billy Bowlegs and his followers to emigrate. Pecuniary inducements were offered to the chief and his people. . . . May 4 was the day fixed for the emigration. On that day the Indians came in from their homes in the Glades, slowly and quietly made their way to the wharf, and silently took their places on the steamer that was to bear them from the home they loved. One hundred and twenty-three had come voluntarily with their Chief; forty-one had been captured. A remnant of the tribe, about a hundred, it was said, remained hidden in the Everglades. They were so few that neither state nor national government made further efforts to remove them.[8]



*Everglades Experiment Station*

ROW UPON ROW OF CELERY PLANTS

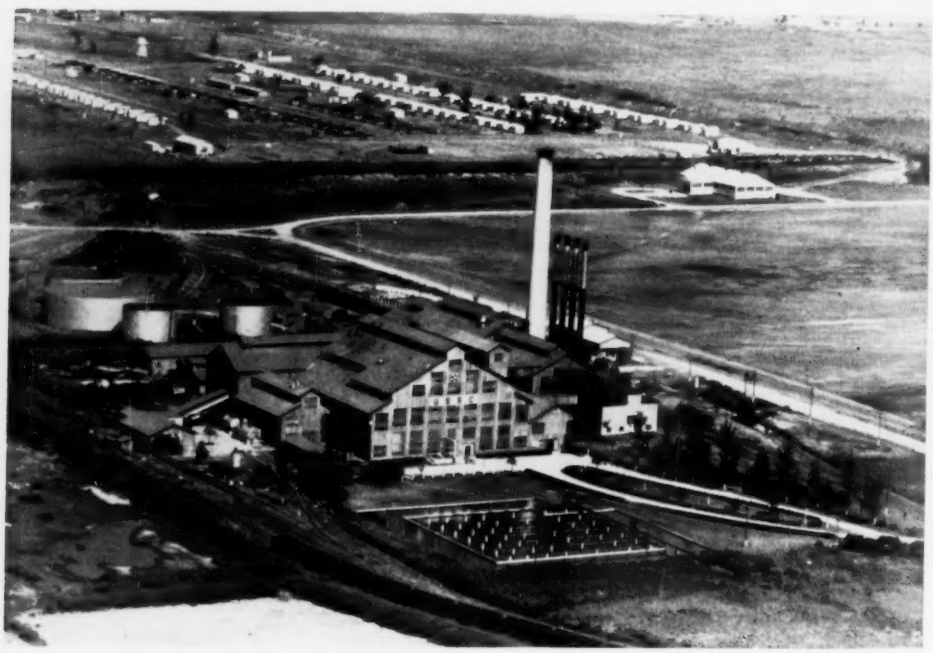
PRODUCTION OF WINTER VEGETABLES FOR NORTHERN MARKETS VIES IN IMPORTANCE WITH THE CULTIVATION OF CANE IN MODERN EVERGLADES ECONOMY. NUMEROUS PACKING HOUSES ARE AN ADJUNCT TO THIS FARMING AREA.

[8] Federal Writers' Project of the Works Progress Administration for the State of Florida, "Florida, A Guide to the Southernmost State," p. 47. New York: Oxford University Press. 1939.

*Everglades Experiment Station*

A CYPRESS HAMMOCK EAST OF LAKE OKEECHOBEE

HERE THE GRASSLAND IS DOTTED WITH OCCASIONAL "CYPRESS DOMES." IN APRIL, 1933, THESE FEW BALD CYPRESSES STOOD AMIDST CULTIVATED FIELDS.



*U.S.S.C.*

SUGAR HOUSE AT CLEWISTON ON LAKE OKEECHOBEE

ON THE SOUTHWEST SHORE OF THE LAKE THE UNITED STATES SUGAR CORPORATION HAS A LARGE SUGAR HOUSE WHICH LOOMS UP CONSPICUOUSLY ON THE LOW HORIZON. IN THE BACKGROUND ARE THE CLEAN, WELL-SPACED HOUSES OF THE WORKERS.

Technically, peace was not concluded with those who remained until the signing in 1934 of a truce and a subsequent treaty.

The Seminoles remaining in Florida lived to themselves, quietly hunting, fishing and gathering turtle eggs.

As late as 1872 there were rumors that an outbreak might take place at any time and consequently, an agent appointed by the commissioner of Indian Affairs visited them in the Everglades to report upon the state of affairs among them. He found them altogether peaceable and living to themselves. Three years later the Commissioner urged that public lands should be secured for their occupation, lest upon them should fall the fate of the Mission Indians of California. But for some time nothing was done.[9]

An Act of Congress had in 1850 granted the swamp lands of the southern portion to the State of Florida. Finally, in 1891, certain lands were set aside for the Seminoles.

Draining of the Everglades was well under way within two decades after the allotment of a reservation for the Indians. Lowering of the water table produced a marked decrease in the supply of game on which the Seminole depended. There appeared to be, moreover, danger that the white man might covet and possess himself of all Indian lands. This latter fear has proved unfounded. In addition to 100,000 acres set aside for them by the State, the Seminoles in Florida own about 26,000 acres of land, part of it purchased for them by the federal government, and the rest set aside for them by executive order.

At present employment is found for Indians desiring to live near settlements on government-directed reservations. Cattle raising is the chief occupation. (In 1938 the reservation at Brighton had around 1,300 head of cattle.)

*Everglades Experiment Station*

STEAM SHOVEL AT WORK ON THE CONSTRUCTION OF A LAKE LEVEE

ORIGINALLY LAKE OKEECHOBEE PERIODICALLY SPILLED OVER INTO THE BASIN-SHAPED EVERGLADES. TO-DAY THE LAKE, WHICH HAS BEEN LOWERED BY A SERIES OF CANALS, IS FURTHER RESTRAINED BY A LARGE DIKE AROUND ITS SOUTHERN HALF.

Since the closing of the Indian wars, Seminole Indians in Florida have increased from nearly 100 to approximately 600. There are four separate bands or tribes (the Big Cypress, the Miami, the Okeechobees and the Tallahassees), but they are all on most friendly terms with one another.

No longer does the Seminole seek to elude the white man; now he desires to attract him.

In one notable instance, where the United States Army and a hundred years of persuasion failed, a highway has succeeded. The Seminole Indians surrendered to the Tamiami Trail. From the Everglades the remnant of this race emerged, soon after the trail was built, to set up their palm-thatched villages along the road and

[9] Brevard, *op. cit.*, Vol. II, p. 199.

to hoist tribal flags as a lure to passing motorists. Like their white brethren, they sell articles of handicraft and for a nominal fee will pose for photographs.[10]

Thus, as the swampy character of the lands disappeared, the Everglades ceased to be a "place of refuge" for the Indians.

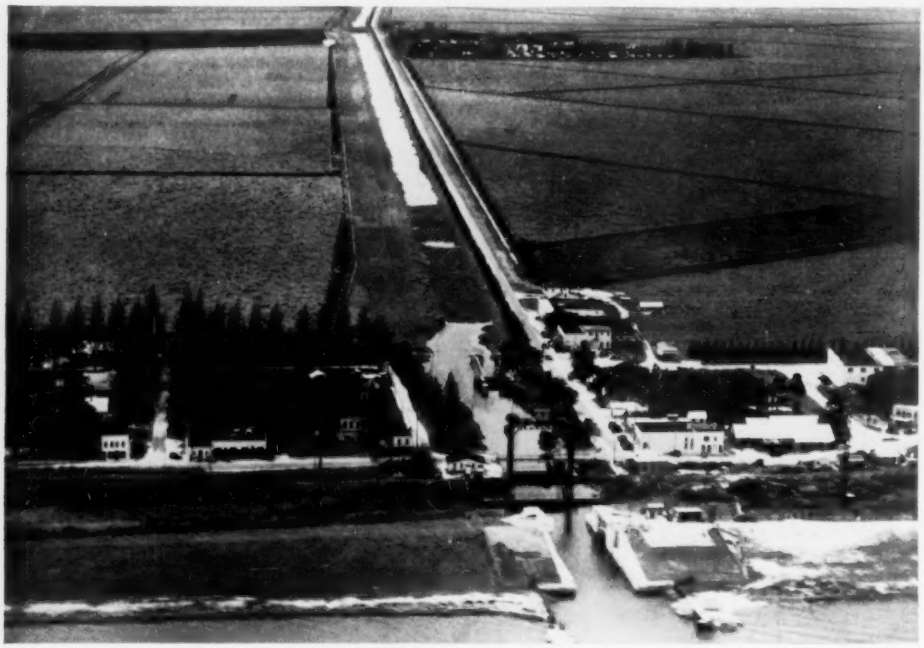
### Confederates

The connection between the Everglades and the Civil War has not been widely publicized. Although several of the Confederate cabinet members fled toward Florida at the close of the war, none sought refuge within the "Glades"; rather, it was the deserter and fugitive who sought a safe retreat there.[11] The marsh concealed both deserters and refugees.

[10] Federal Writers' Project, "Florida," p. 5.
[11] Norton, *op. cit.*, p. 269.

### Outlaws

So long as transportation within the Everglades was poor, it continued to be a hiding place for individuals who sought safety and sanctuary. Whether they were fugitives from justice or injustice, moonshiners or murderers, criminals of the chain gang or mere honest smugglers, the Everglades harbored them and concealed them. Most notorious of criminals there were members of John Ashley's gang, who from 1910 to 1924 robbed banks and hi-jacked liquor trucks, secure from capture because they were "swallowed up" by the tract of marsh after each crime. The whole district breathed easier after Ashley and three of his followers were killed in gun battle at the Sebastian River bridge, in November, 1924.



*U.S.S.C.*

LOCK IN THE WEST PALM BEACH CANAL

CANALS SUCH AS THIS TRANSFORMED THE EVERGLADES FROM AN ALMOST IMPENETRABLE MARSHLAND TO A PRODUCTIVE FARMING REGION. NOTE THE LEVEE, LOCK AND VILLAGE OF LINEAR PATTERN IN THE FOREGROUND AND SUGAR CAMP, PUMP HOUSE AND CANE FIELDS IN THE BACKGROUND, CRISS-CROSSED WITH LATERAL CANALS.

*F. C. Scott*

FIVE SEMINOLE INDIAN COWBOYS AND A WHITE MAN

That the flat terrain of the "Glades" can easily be used for airplane landing fields was turned to commercial advantage at one time.

During the "dry" period of national prohibition, the Everglades proved a veritable godsend to a small army of gentlemen engaged in the somewhat risky but highly remunerative game of rum-running. Swift airplanes, laden to the limit with Bacardi, whiskey, gin, and other wet goods from Bimini, Grand Bahama, Nassau, or even Cuba, would come roaring into the Everglades, and, dropping down to secret landing fields, would be met by motor cars and trucks with little fear of being caught by federal or state officers.[12]

The coming of paved highways has necessarily exposed would-be fugitives in the "Glades" to danger of capture. As shipment of its farm produce has become easier, the value of the Everglades as a place of retreat has declined.

### Period of Exploration and Exploitation

An anomalous region—neither truly land nor truly water—the Everglades touched the imagination of many who viewed it. They envisioned it not as a vast barrier and waste land, but yielding to man its richness of soil, the surface water having been removed in some way. In the nineteenth century the marsh was more adequately explored and exploitation was begun.

The first white man to visit the Everglades may well be forgotten, for he came unwillingly and left virtually no record of his stay. Early in the sixteenth century this Spaniard, Escalente de Fontenado, was shipwrecked in the Strait of Florida and carried into captivity by the Cacique tribe of Indians. Although he was released after seventeen years, little was learned from his scanty accounts of the character of this prairie.

The "Glades" seem to have been given slight attention until after Florida came into the possession of the United States. Fifteen years later, in 1834, an act was passed "for the purpose of facilitating the drainage of lands." During the territorial period, indeed, was the first discussion heard of the drainage of the

[12] A. Hyatt Verrill, "Romantic and Historic Florida," p. 114. New York: Dodd, Mead and Company. 1936.

FIG. 3. U. S. WAR DEPARTMENT MAP OF FLORIDA MADE IN 1856

THIS MILITARY MAP OF FLORIDA SOUTH OF TAMPA BAY, IN ALL ITS MINUTE DETAIL, WAS ENGRAVED ON STONE. INDICATED BY SEPARATE LITTLE SIGNS ARE SUCH ITEMS AS PINE, OAK, CYPRESS AND PALMETTO TREES; DWELLING HOUSES; OCCUPIED AND UNOCCUPIED FORTS; AND BATTLEGROUNDS.

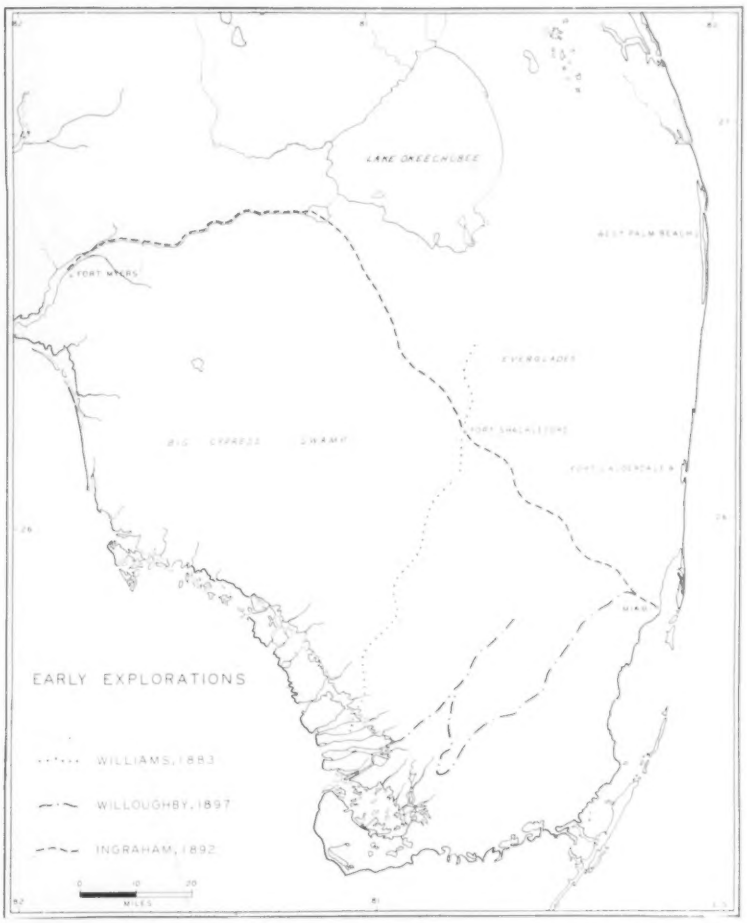



FIG. 4. MAP SHOWING EARLY JOURNEYS THROUGH THE EVERGLADES

Everglades. Not until many years later, however, was action taken in this direction.

It was the war with the Seminoles that brought the Everglades into prominence. Three effects may be noted. First, there was some public discussion of the question of draining these lands, even though the subject did not evoke great interest. Second, there were expeditions bent on exploring the region, under the leadership of Marchand and Roger in 1842, and of Lieutenant Martin in 1847. In 1855 Captain Dawson reconnaissanced with an Indian guide and a considerable party. And, finally, the War Department published in 1856 a map of southern Florida, remarkable in detail and accuracy (Fig. 3).

Once the Civil conflict and its immediate repercussions had passed, the Everglades again engaged the attentions of adventurous souls. In 1881 drainage was begun in the northwest quadrant of the "Glades" by the Diston Company. From 1883 to 1897, explorers boldly traversed the hitherto inaccessible portions (Fig. 4). "The first attempt to make a lengthened journey through any part of the Everglades in the interest of geographical research was made by A. P. Williams in 1883, the expense of which

*F. C. Scott*

SEMINOLE CATTLE ON THE GLADES COUNTY INDIAN RESERVATION

CATTLE RAISING IS INCREASING ON PLANTED PASTURES IN THE UPPER GLADES.

was covered by a southern newspaper. This was called the '*Times Democrat* Expedition,' (*New Orleans Times Democrat*). . . . "I fear, however," writes Willoughby in 1898, "that accurate survey must have been abandoned at a very early stage, as I can find no map with any stations, the line being devoid of points from start to finish, and simply gives a general direction from the Harney River to Lake Okeechobee."[13] Later a party of twenty-two, led by J. E. Ingraham with J. W. Newman as engineer, traveled from Fort Myers to Fort Shackelford and thence to Miami. The report of this expedition led to extension of the Flagler railroad south along the east coast of Florida, reaching the present site of Miami in 1895. In his journey of 1897 Lieutenant Hugh L. Willoughby crossed the "Glades" in the latitude of Miami.

At the opening of the nineteenth century, the Everglades was an unexplored marshland impeding exploitation, useful only as a place of refuge. At the close of the century, enough was known of its nature that successful drainage operations could immediately be enterprised.

[13] Willoughby, *op. cit.*, p. 21.

# STRUCTURE OF THE WOOL FIBER AS REVEALED BY THE MICROSCOPE

By Dr. CHARLES W. HOCK

RESEARCH ASSOCIATE OF THE TEXTILE FOUNDATION, NATIONAL BUREAU OF STANDARDS

SINCE antiquity the hair-like covering of the sheep has been spun and made into cloth. Although all animal hairs are similar, the wool of the sheep combines to an unusually high degree those properties which make a material suitable for the manufacture of textiles. During 1941 the amount of wool consumed in the United States reached an all-time high of 652,200,000 pounds. This poundage represents an enormous number of individual fibers. It is, however, upon the structure of the single fiber that the useful properties of the finished fabric are ultimately dependent. What, then, is the structure of the wool fiber?

To the naked eye wool fibers look like simple filaments, not greatly unlike cotton, silk or rayon. Through the eyes of the microscope, however, the minute architecture of the fibers is revealed, and under these conditions of examination the wool fiber shows many characteristics whereby it can be distinguished from other fibers which it resembles superficially.

All animal hairs, including those of man, are similar to each other with respect to their origin and growth and to their physical and chemical properties. They arise as appendages of the epidermis, or outermost layer of the skin, and

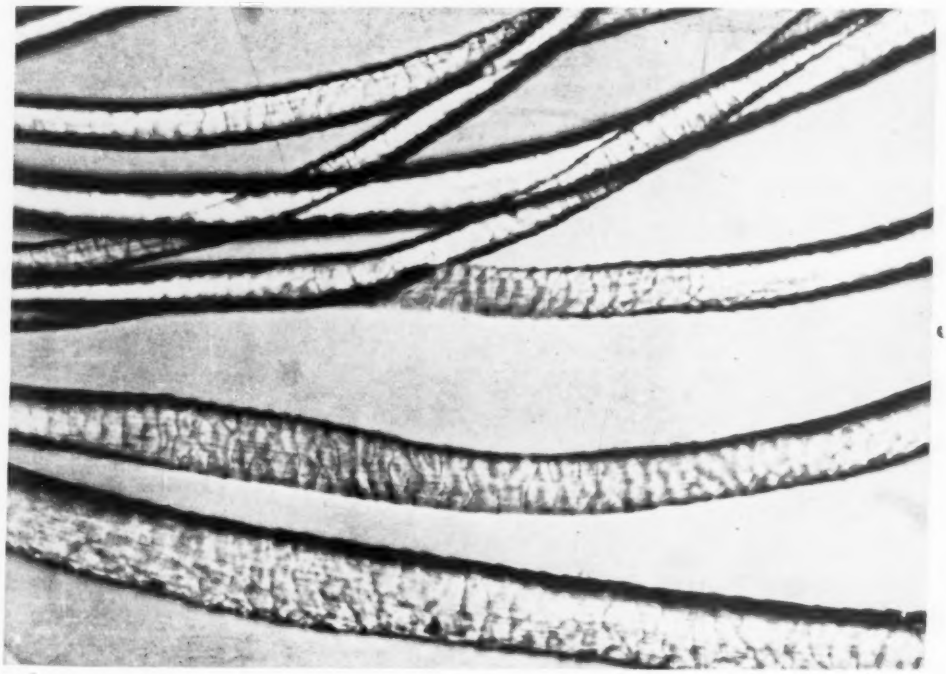


FIG. 1. SEVERAL WOOL FIBERS

THE OUTLINE OF THE SCALES IS FAINTLY VISIBLE. MAGNIFICATION × 150.

show resemblances to related structures such as nails, horns and feathers. Each fiber consists of a root and a shaft. The root is situated in a pit below the surface of the skin and is made up of cells which are all more or less alike. The fiber increases in length by the proliferation of new cells in the root and the subsequent emergence of these cells into the shaft. The shaft is composed of dead cellular units which are usually arranged in three layers—an outer layer of scales, a middle region called the cortex and a central core or medulla. The relative thickness of each of these layers varies considerably in different fibers. In the best grades of wool the medulla is absent or very small.

In the microscopic examination of wool the fibers are usually mounted in a liquid, frequently water, as this renders their characteristics more distinct. Even under low magnification the scales on the surface of the fiber can be discerned (Fig. 1). Their size, shape and arrangement differ in various types of wool and are often sufficiently characteristic to permit identification of the fiber. Although much can be learned about wool fibers by examining them in an aqueous mount, this method yields little information about the detailed structure of their constituent cells. In order to study the minute structure of the various types of cells, the fibers must be treated in a way that makes a more detailed microscopic examination possible. For this purpose thin cross (Fig. 2) and longitudinal sections can be employed to good advantage, but the liberation of single cells from the fibers is even more satisfactory. Chemical reagents, enzymes and microorganisms can be used as tools to break down wool fibers into their constituent cells. Fig. 3 (A, B and C) shows, for example, fibers which have been attacked by enzymes, with a resultant breakdown. Although the scales are relatively resistant to this action, most of the cortical cells have been separated from each other and removed from the fiber.

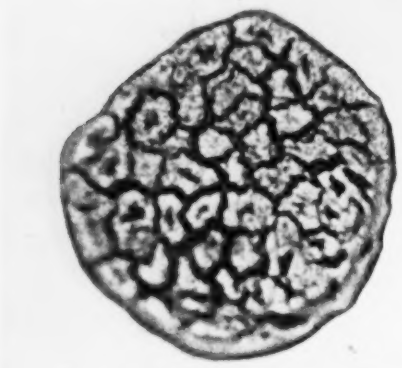


FIG. 2. FIBER CROSS SECTION
THE THIN SCALE LAYER OF THE WOOL FIBER, AND THE CORTICAL CELLS WITH THEIR NUCLEI ARE VISIBLE, BUT NO MEDULLA IS PRESENT. MAGNIFICATION × 1500.

The cortical layer, to which the strength and elasticity of wool are mainly attributed, forms the largest part of most wool fibers. This layer is made up of cells which are spindle-shaped and which vary in size depending on the sample of wool. About 300 of them placed end to end would extend one inch. Placed side by side it would take about 10 times that many to cover the same space. Near the center of each cell a structure resembling a nucleus can be detected. The nucleus is granular, whereas the rest of the cell has a fibrillate appearance (Fig. 4, A). The two regions differ also in their staining properties and in their appearance in the polarizing microscope. When examined with the latter instrument the nucleus appears as a dark, elongated area in a bright cell (Fig. 4, B). This clearly indicates differences even within a single cell. The fibrillate appearance of the cortical cells is due to the presence of fine, thread-like structures which lie parallel to each other and which can be separated by the fine glass needles of a micromanipulator. Figure 5 (A, B and C) shows a single cortical cell being dis-

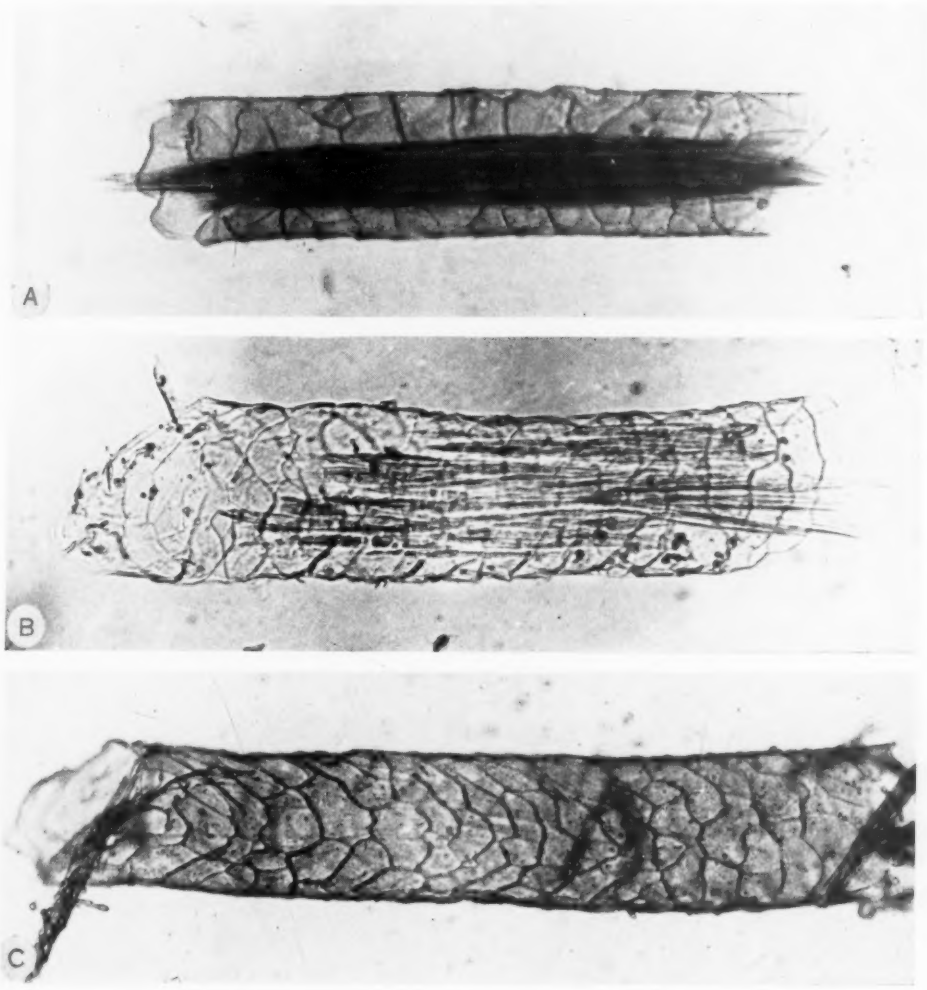



FIG. 3. WOOL FIBERS ATTACKED BY ENZYMES

IN *A* AND *B* SOME OF THE CORTICAL CELLS REMAIN IN THE FIBER, BUT IN *C* THEY HAVE BEEN REMOVED ENTIRELY, LEAVING ONLY A HOLLOW TUBE OF SCALES. MAGNIFICATION ×425.

sected into its constituent fibrils. In this connection it is interesting to note that no matter how far natural textile fibers like cotton, flax, silk and wool, are subdivided they always have a fibrous structure. Recent studies show that even at the high magnifications obtainable with the electron microscope, the fibrous nature of these fibers is still evident.

The scales form the surface of the fiber and serve as a protective armor. As many as several thousand of these thin irregular plates cover every inch of fiber surface and present a multitude of beautiful forms. The scales overlap each other in a manner comparable to the arrangement of shingles on a roof or scales on a fish (Fig. 6). They show little internal organization such as exhibited by the cortical cells and with fine needles it is not possible to dissect them into fibrils. Examinations with the

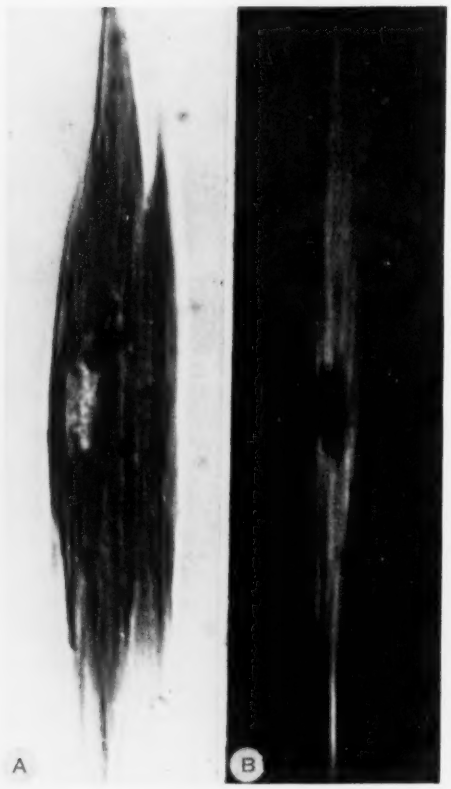



FIG. 4. SINGLE CORTICAL CELLS

*A* SHOWS THE GRANULAR NUCLEUS AND THE FIBRILLATE APPEARANCE OF THE REST OF THE CELL. IN *B*, THE DIFFERENCES IN ORIENTATION ARE DETECTABLE WITH THE POLARIZING MICROSCOPE. MAGNIFICATION × 1275.

polarizing microscope indicate, furthermore, that the material in the scales is not highly oriented.

The central core or medulla, when present, consists of rather large cells which contribute little to the desired mechanical properties of the fibers. By careful breeding of the sheep, wool has been obtained in which the medulla is absent, the fiber in such cases consisting of only a cortex surrounded by a layer of scales. Pigment, when present, is distributed in the medulla and cortex, in the form of small particles.

Since the cells of the root are alive and growing, whereas the cells of the shaft are dead, it is not surprising to find profound differences between these two regions of the fiber. Some of these differences are revealed upon examining fibers which have been pulled from the back of a sheep so as to have the roots attached to the shaft. The root is found to be soft and easily crushed, whereas the shaft is tough and horny. A micro-

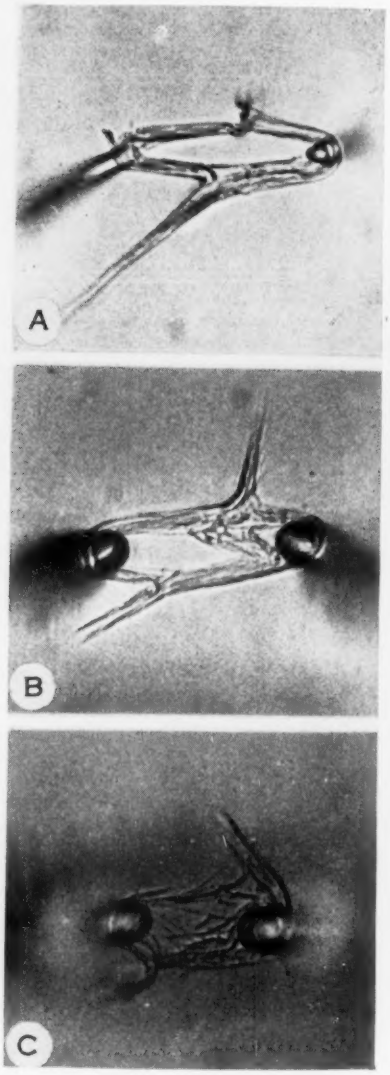



FIG. 5. DISSECTION OF CELLS

THREE CORTICAL CELLS BEING DISSECTED WITH MICRO NEEDLES TO SHOW THEIR FIBRILLATE STRUCTURE. MAGNIFICATION × 575.

scopic examination shows that all the cells of the root are more or less similar. They are round in shape and have a granular appearance. On the other hand, the cells in the shaft are elongated, fibrous in appearance and are differentiated into distinct layers, as previously described. Observations with the polarizing microscope show that the material in the shaft, unlike the material in the root, possesses a relatively high degree of orientation.

Besides differences in cellular structure, a comparison of the root and shaft also reveals differences in chemical structure. Thus, for example, when certain microchemical color tests are applied, the two regions frequently differ in their reactions. The nuclei in the cells of the root react positively to tests for nucleic acid, whereas the nuclei in the cells of the shaft do not produce the red color indicative of a positive test (Fig. 7). Similarly, when the fibers are tested for chemical groups called disulfides, only the shaft gives a positive test. These observations show that as the cells of the root mature and pass out into the shaft a number of physical and chemical changes take place simultaneously. A knowledge of these changes and especially of their relation to the structure and properties of the fiber is essential for the best utilization of the fibers during manufacture.[1]

FIG. 6. WOOL SCALES

A GROUP OF SCALES AFTER RELEASE FROM THE FIBER. MAGNIFICATION × 1475.

FIG. 7. ROOT AND SHAFT

PART OF A FIBER WITH ROOT ATTACHED, SHOWING DIFFERENCES IN STAINING PROPERTIES OF THE TWO REGIONS. MAGNIFICATION × 120.

[1] This paper is based on "Microscopic Structure of the Wool Fiber," by Charles W. Hock, Robert C. Ramsay and Milton Harris, which appeared in the *Journal of Research of the National Bureau of Standards*, 27: 181–190, Research Paper 1412, the *American Dyestuff Reporter*, 30: 449–456, and *Textile Research*, 11: 415–428, August, 1941.

# STRANGE STORIES OF FISH

By Dr. E. W. GUDGER

HONORARY ASSOCIATE IN ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY

It is well known that in certain parts of the world, particularly in Africa, certain birds accompany large herds of grazing mammals, to feed on the grasshoppers and other insects that are stirred up by the forward-moving beasts. This is a curious and interesting feeding relationship. But in this same Dark Continent there is a closer, more curious and more interesting one between two species of small birds and the rhinoceroses. These little birds light on and run about over the backs of their friends and hosts, seeking for the ticks found in and around the folds of their skins. Thus they free their hosts of these annoying blood-sucking parasites and get their own food at the same time. And in return for their free meals, the "rhinoceros birds," on the approach of danger, rise up and with loud chatterings warn their hosts. This relationship is well established and well known, but that fishes should relieve cattle of annoying flies and men of ticks is surely something new under the sun.

Insects are one of the chief foods for a large category of fishes, but for the most part these insects are the forms that either live in or near the water or spend their early lives therein. In short, when we speak of insects as food of fishes, one means those forms that may properly be designated "water insects." But, on the other hand, this short article has to do with the most unusual and extraordinary kind of insect food that any fishes ever ate. These fish-eaten insects are dry, very dry, land forms, which on

A CHUB PICKING BLOOD-SUCKING FLIES FROM A COW

THE LITTLE CHUBS HAVE BEEN OBSERVED IN THE NIOBRARA RIVER IN KANSAS TO JUMP NEARLY A FOOT OUT OF THE WATER TO REACH FLIES ON THE SIDES OF CATTLE.

vegetation lie in wait for and attach themselves, as bloodsuckers, to men and animals. This parasitism has long been known, but the manner in which the fishes get their food from these hosts has (so far as I know) been described by but three writers.

The tropical explorer, Ivan T. Sanderson, in his delightful book, "Living Treasure" (New York, 1941, pp. 89 and 90), tells a story of how little fishes in a stream in Honduras relieved himself and his companions of a multitude of viciously infesting ticks. The story is interesting and we will let him tell it in his own words:

> It has been suggested that Pandora opened her blasted little box on the upper Orinoco River in South America. If this is true, she must have been a British Honduranean and have collectel her pests in her homeland, for the place is the very epicentre of all biting six- and eight-legged pests. Among these are small ticks, known locally as warri-ticks, which come in two sizes: adults at one and a half pinheads and by the hundreds, and immature at a pinpoint and by the thousands. These abominations lie in solid bunches on stalks, bits of grass, and so forth, awaiting the passage of some greater beast. If you touch such a congregation, they all flood onto you in what is literally the flicker of an eyelid of time. Then they spread out like a *Panzer* column and infest the whole of you, and there is only one sure cure. You undress, leave your clothes, jump into the nearest billum pool, and then try to lie quiet. The little billums get to work, and in no time divest you of every tick. The operation drives you nearly crazy, but it is better than the torture inflicted by the ticks should they get at your skin.

It is a matter of much regret that Sanderson did not get a photograph or at any rate make a sketch of this most interesting incident. But he does add this further account of the activities of these helpful little fishes, which he thought were cichlids but which were not collected and positively identified:

> Now I can't find out whether this is a purely British Honduranean word for a special kind of fribble, but these billums are common enough in other tropical countries. In fact we have often encountered them, though I must admit that never before had they quite such an individuality. "Billums" is a general term in British Honduras for little fish in fresh water. Now little fish infest most streams in the tropics, and in many they come and tickle you if you lie quiet, but in British Honduras their activities are so single-minded and so determined that they have gained for themselves this special title. As soon as you enter the water, they dash at you and start tickling. They nibble gently at your toes and your elbows, they pull the hairs on your legs in a playful manner, and they float around in swarms with their watchful little eyes upon your every movement. You can't drive them off and yet you can't catch them even if you tempt them with bread crumbs in a net. They are frightfully cunning. They are most remarkable little people.

This will seem preposterous to some of my readers, but are they right? For twenty years, I have carried in a poor memory the faint recollection of two corroborating accounts. Let us look them up and consider them.

One relates how small fishes rid cattle of their infesting insect parasites. This is contained in a short article—"The Chub and the Texas Horn Fly" by Roy L. Moodie in the *American Naturalist* for March, 1909. The previous summer (1908), while on a fossil-hunting trip in country drained by the upper reaches of the Niobrara River in Kansas, his attention was called to the great numbers of horn fly (*Haematobia irritans*) on the stock in the neighborhood. This fly is so named because it has the habit of clustering around the bases of the horns of cattle to suck their blood. It is a great pest. However, since the cattle under observation were for the most part "muleys," the flies would settle all over their backs and sides. The little fish in this case is scientifically known as *Semotilus atromaculatus*. Here is how the cattle obtained water and at the same time got themselves freed of their pests:

> The cattle would almost always enter the stream at the shallow part of the ford and gradually wade up stream, drinking as they went, until they came to the deep place near the fence where the water reached well up to their bellies. The chubs seemed to be unusually num-

erous at the ford, and we often wondered at the great numbers of the little fishes which we could see in schools in the clear water. Their presence was soon explained. As soon as the cattle entered the stream at the shallow place in the ford the chubs would come out from their cool and shady retreats under the grasses along the sides of the bank and hasten to meet the cattle at the shallows. Often we saw as many as a dozen or more chubs following a single cow. As soon as the water came near the bellies of the animals the chubs would leap out of the water and catch the horn flies from the sides of the cattle. Often we saw them leap as much as half their length out of the water to secure a fly which was high up on the animal's sides. These observations were made on several consecutive days, and on the last day but one I was so fortunate as to secure a photograph of a chub in the act of catching a fly from the side of a cow and the photograph is published herewith.

That the fishes actually learned that the dark spots on the sides of the cattle made good food, there can be no doubt. Just how they first learned it we may not know. The chubs had further learned that the coming of the cattle meant food for them, hence they would meet the cattle in the shallows and follow them to deeper water. The act of these fishes leaping to secure flies from the sides of cattle is so unusual that it is deemed worthy of notice and it is hoped that the incident may be of service to those interested in animal behavior.

Dr. Moodie says further: "Mr. Albert Thomson called my attention to the actions of the fishes and we together made the . . . observations." The Mr. Thomson referred to is our Albert Thomson, head of the laboratory of paleontology in the American Museum. He tells me that he repeatedly saw the chubs picking the flies from the cattle, and that they would sometimes jump nearly a foot out of water to get a fly.

The photograph from which the cut was made was a poor one. The resulting poor cut was printed on soft paper, and the impression during thirty-three years has faded. Dr. Moodie died some years ago and the negative has disappeared. It was necessary to photograph the figure on the printed page and then partially to redraw it. This, skilfully done under my supervision, has been chiefly the painting in of a background and the sharpening of outlines—things that should have been done before the photograph was sent to the engraver. The essential features of cow and fish are as they were in the original. The amended photograph, as reproduced herein, along with the printed figure of 1909 have been shown to Mr. Thomson, and he states that this new illustration accurately portrays what he saw take place.

But what about the other reference to fishes doing a similar service to men? This is contained in the *American Naturalist* for January, 1872. On page 48 is the following account credited to "Exchange." It is greatly to be regretted that more is not known of the source:

Fishes as Surgeons.—In walking through the long dank grass of the forest, an almost imperceptible, minute sort of ticks attached themselves to the ends of our trousers, and from thence up our legs and buried themselves in the flesh, causing a most annoying sensation of itchiness. The whole party soon became victims to the irritation of this little pest, and scratched and exclaimed without measure. One of the Caribs, on hearing the cause of our vexation, said that the remedy was near, advising us to go without one moment's delay and lie down in the river, and that there was a small fish in the creek which would almost immediately extract the tick if it had not burrowed too far into the flesh; we all did as I fully expect you to do, gentle reader, on hearing this novel style of surgery, burst out into uncontrollable fits of laughter; but on Mr. C— and the manager assuring us that the blacks only spoke from long experience, and that they themselves had more than once proved the efficacy of the cure,—warning us at the same time that the tick, if not soon extracted, would become a very severe sore; we at last, but without one atom of faith in the experiment, assented to the proposal, and commenced to undress without further opposition.

We bathed, and then in compliance with the Carib's directions, lay down quite still in the shallowest part of the stream. In a few moments, I felt something very sharp strike against several parts of my body; cautiously raising my head, and looking down towards my legs I saw a swarm of very small fish, wriggling and swimming around me, continually bobbing their little heads at my person, and readers, ridiculous, in-

credulous as I fear my story will sound in the ears of the unlearned, positively the fish not only picked off the ticks which were outside the flesh, but actually extracted those which had burrowed beneath the skin.

No locality is given, but it must have been on some of the islands bordering the Caribbean Sea, or on the mainland part of South or Central America bordering the same sea. What the fishes were is not known. If the locality was on the mainland, these fishes may have been the young of or possibly a small species of Characin. This is conjectured on the basis of the following data:

Bearing on the origin of this habit in these tropical fishes are certain observations made by Dr. C. M. Breder, Jr., director of the New York Aquarium. Some years ago while collecting fishes in the Rio Chucunaque, Panama, and studying their habits he noted this curious and interesting behavior in a small Characin, *Astyanax vuberissimus*. These little fishes were found to be greatly attracted by human excretions and were noticeably attracted to the region of greatest abundance of perspiration—*i.e.*, to the armpits and crotch. Here they would nibble and bite assiduously at the hairs. "When these secretions had been washed away, these regions no longer possessed superior attractions and the little fishes distributed their tiny attacks over the whole body, particularly where there were warts, calluses, moles, or clumps of hair on which they could lay hold."

The region in which Dr. Breder and his men were working was not a particularly "ticky" region, and he did not see the little fishes hunting for ticks, nor did he happen on any accounts of such activities. But judging from the avidity with which the fishes attacked calluses, moles, pimples, warts, etc., he does not doubt that if men infested with ticks were to get down in the water the little Astyanax fishes would quickly rid them of these unwelcome bloodsuckers.

Ticks form a pretty steady diet for the rhinoceros birds, since all live in the same milieu—air. But flies and ticks are a most intermittent food supply for fishes, since the two kinds of animals live in the most diverse environments—air and water. For the fishes, ticks and flies come—like the manna of the Israelites—from the heavens.

## SCIENCE AND SOCIETY

WHILE scientific knowledge is providing unparalleled instrumentalities for achieving an orderly and humanly significant social life, science can not minister effectively nor safely to man and his society until it is oriented to our contemporary social life and coordinated into the complex functioning of our culture. To-day ignorance of human behavior and social organization, and the prevailing unawareness of the functioning of our culture are blocking the full utilization of scientific knowledge. Thus we have the ironic and tragic spectacle of science contributing effectively to man's physical comfort or to his destruction, but seemingly helpless to advance his social and cultural aspirations.

The relation of science to society involves more than questions of the organization and immediate application of scientific results through technology and professional practice; it raises the more important issues of the place, function, and especially the responsibilities, of the scientist in the present-day social situation and cultural confusion. There is a serious lag between scientific knowledge and its application to human needs, . . . also a widening gap between scientist and layman, to whom science and technology often appear as esoteric pursuits.

Moreover, the very rapid progress of scientific knowledge has rendered obsolete much of our traditional culture and ancient beliefs and in so doing has fostered individual confusion, distortion and insecurity. Personalities so disturbed can not function adequately as individuals nor participate as members of a society which is seeking resolution of its difficulties by voluntary cooperation. The increasing social disorder, affecting those countless millions in all lands who have been cut loose from their inherited social, economic and ethical moorings, has rendered them subject to devastating exploitation by distorted, but plausible, fanatics. To-day society itself has become the patient.—*Report of the President, Josiah Mack Jr. Foundation.*

# HALF A CENTURY WITH THE SUCCESSFUL ARGENTINE ANT

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On one fine day, fifty years ago, Ed Foster,[1] journalist and amateur entomologist, while leisurely collecting Hymenoptera, made a mental note of an innocuous-appearing brown ant. Foster, on this eventful day, devoted his entomological talents to that section of New Orleans where the coffee ships from Brazil were docked. It was not until some twenty years later, and only after the ant had become the housewife's nemesis, the gardner's grief and the orchardist's plague that he recorded his first glimpse of what is now our most prominent ant pest, namely, the Argentine ant.[2]

This insect undoubtedly was present some years prior to Foster's observation, but it only came into the public's eye with the turn of the century. The alarmed populace of New Orleans christened it the "New Orleans" ant. Newell,[3] deeming this to be a dubious honor for the Crescent City, shortly designated it the "Argentine" ant due to the fact that the species was described from workers collected in Buenos Aires, Argentina. Since the coffee ships that conveyed the ants to the docks of New Orleans came from Brazil, never from the Argentine, and since the insect was better known in Brazil, probably its native habitat, he might have called it more appropriately the "Brazilian" ant.

This most successful insect is now established throughout the southern states and in California. Isolated infestations have been reported from Arizona, Missouri, Illinois, Maryland, Oregon and Washington. It is also known from Portugal, the Union of South Africa, France, Australia and from many islands.

## Injurious Aspects of Argentine Ant

The Argentine ant is one of the most important as well as one of the most common household pests in the wide area over which it is distributed. For example, in those sections of southern California where the insect is prevalent, practically every housewife utilizes some measure to combat it. In homes where its control is neglected, hordes of this persistent creature with its ever-present trails may be found in practically any food of a sweetish nature. It is an extremely persistent pest, especially so during the warm summer months. In the winter, immediately after the rains, it may invade the home in protection from the inclement weather.

That the Argentine ant was a most serious household pest in New Orleans may well be realized when we peruse Newell's remarks anent this ant:

> The species does not sting, but can bite severely when so inclined, and sometimes becomes an annoyance to human beings. I have known of several cases where people have had to place their beds, during the summer months, upon panes of glass covered with vaseline in order to pass the night in peace. There have been rumored cases of infants being killed by these ants, but so extreme a case has not come within my observations. That such might easily occur is not at all improbable.

[1] E. Foster, *Jour. Econ. Entom.*, 1: 289–293, 1908.

[2] *Iridiomyrmex pruinosus* Roger var. *humilis* Mayr.

[3] W. Newell, *Jour. Econ. Entom.*, 1: 21–34, 1908.

Barber[4] was given this rather graphic description of the attack of the ants on a 4-weeks-old baby:

"We were awakened in the night by a weak cry from the baby, and when the light was turned on the baby's face was black with ants. They were in the baby's nose, ears and mouth. We hurriedly carried the baby to the bathtub and started to wash off the ants. It took us nearly an hour and a half to get the last ant off the baby. I feel sure that if we had not heard the cry, in a few hours the child would have perished."

Some twenty years later, Lyle[5] further indicts this insect with the following notation:

Negroes in some of the badly infested towns in Mississippi, long since accustomed to eating ants in all their food, seek partial relief while sleeping by stuffing cotton in their ears. Sleeping children with cuts on their bodies suffer especially from their attacks. The possibility of spreading typhoid fever or other diseases is indicated by their attendance on human feces in outdoor privies.

The farmer is another victim of the ant's depredations. Newell, who made the first and still most comprehensive studies of the Argentine ant, conjured a skin-creeping specter when he stated that the ant would be as bad a pest as the San Jose scale, the gipsy moth and the cotton boll weevil. Thanks to the entomologist, this dire prognostication has never been realized. In the citrus orchards of Louisiana, some thirty-five years ago, the ant was incriminated for eating the buds on the trees and thereby ruining the yield. Fig crops were likewise damaged. Moreover, this hexapod fostered aphids, mealybugs and scale insects on plants so that they increased enormously in numbers, and then these injurious insects would have the plants in a most serious way. The Argentine ant was an especially prominent pest in the citrus orchards and sugar-cane fields in Louisiana.

[4] E. R. Barber, *U.S.D.A. Bull.* 377, 1916.

[5] C. Lyle, *Jour. Econ. Entom.*, 29: 965–967, 1936.

### Beneficial Aspects of the Ant

The Argentine ant has a few virtues, but these hardly compensate for its numerous vices. It is, above all else, an important scavenger of dead and dying insects. In the homes of the poor in New Orleans, it has played the role of Robin Hood by exterminating bedbugs and other vermin. The sorghum midge and other injurious insects are very often victims of its appetite. On a day in spring when the western subterranean termite conspires to populate the earth with house-consuming insects, the ant may be observed bearing the winged termite to some subterranean festive board. The ant apparently has little success against the termites when they are ensconced in their earthen tubes.

### Food of the Argentine Ant

The Argentine ant has a decided "sweet tooth" which it does not hesitate to reveal when in the presence of sugars, syrups, fruit juices and materials of a like nature. It feeds with great avidity on the floral and extra-floral secretions of plants and consumes with gusto the honeydew excreted by aphids, mealybugs, scale insects, etc. Meat, especially that of other insects, is at times very attractive to it, and often one may see the ant in great numbers on a fresh bone abandoned by a dog. In Berkeley, California, the insect often invaded the university hospital and fed on blood smears. It is also recorded feeding on cereal products, especially on corn meal.

When once on the trail of food, the ant is extremely persistent. It raids refrigerators with the same abandon as any member of the family and, like Eliza in "Uncle Tom's Cabin," will even cross ice to attain its objective. The ant has been observed to drop from the ceiling on a table which had its legs wrapped in cloths soaked with coal oil, and has entered tightly screwed Mason jars, lack-

ing in a rubber gasket, by following the spiral thread between the cover and the glass.

There are certain plants which are almost certain to attract myriads of this insect, and the ants, at times, will be found ascending these plants in trails that are several inches wide. Cherry laurel is one of the "ant-plants," and the Argentine ant fondly feeds on the secretions from the nectaries on the leaves. During the summer months when the insect ascends this plant, it will not be turned aside by the most seductive of baits. Fig trees, with their fresh figs, are an ant heaven and bamboo, many species of pine, as well as numerous other plants infested with aphids and other Homopterous insects, constantly shower the hungry emmet with their "manna."

The harassed housewife is apt to attribute certain occult powers to this insect, so quickly does it locate food in the home. The ant accomplishes this feat despite relatively poor eyesight, and a sense of smell rather limited in range, so that it practically "bumps" into the nourishment before discovering it. To explain this, we need not travel into the realm of legerdemain. Newell and Barber[6] found that the ant can travel 29 inches a minute or 145 feet in an hour, and thus the scouts who forage day and night, and patrol every square inch of an infested area, are bound to contact some stray victual. They thereupon report the gastronomical bonanza to the home base, and the characteristic safari of ants ensues. In hot weather the rate of locomotion of the ant, as with other insects, is greatly accelerated, and it finds its food with even greater alacrity.

### Relationship to Honeydew-secreting Insects

The economic entomologist is greatly interested in the Argentine ant because of its habit of fostering and protecting injurious insects on plants. Horton[7] clarified the relationship between the Argentine ant and a typical honeydew-secreting insect, the injurious black scale. He states:

> The ant approaches a mature or immature but settled insect and strokes the body with one antenna after the other, rapidly and rhythmically. If no liquid appears after 15 or 20 strokes, the ant usually passes to another scale or rests motionless by the first. Unless the scales are very numerous a proportion of the ants always are waiting, and the principal function of the small shelter structures found over scale groups is believed to be to protect the waiting ants from light, breezes, and sometimes, the too copiously falling honeydew and its attendant mold. When the scale is ready to excrete the anal plates open slowly outward and from between them is extruded a tubular organ, at the extremity of which appears a droplet of colorless fluid. This the ant takes and swallows at once. The tube is then retracted and the anal plates close. The whole operation requires only a few seconds, not allowing time for closer examination of the mechanism.

Horton noted that the process was somewhat similar in the mealybugs, that the ants destroyed but a negligible number of orange blossoms, that it did not disseminate the living scales, that it prevented parasites and predators of the scales from functioning, and thus intensified the effect of these injurious insects on the tree. He then concluded that as a whole the ant was not too important in citrus orchards in the building up of scale population, but was of some importance in spreading plant diseases on trees.

Students of insects have had proof for many years that ants may carry aphis and other homopterous insects on to plants and aid them in becoming established there. There is a difference of opinion amongst entomologists as to whether or not the Argentine ant actually carries scale insects on to the plant. Horton, as was previously mentioned, definitely stated that the Argentine ant

[6] W. Newell and T. C. Barber, *U.S.D.A. Bur. Entom. Bull.* 122, 1–98, 1913.

[7] J. R. Horton, *U.S.D.A. Bull.* 647, 1918.

did not disseminate the black scale. Newell and Barber came to a different conclusion, as the following observation will indicate:

> During March, 1910, a considerable number of adult female scale insects were found embedded in a band of "tree sticky" placed around a magnolia tree to repel the ants. The band was located 4 feet from the ground. The scale insects were a species of *Odonaspis* which is found upon Bermuda grass close to the surface of the ground. There was apparently no other way for the insects to get up the tree except through the transporting agencies of the ants.

### Relationship of the Argentine Ant to Other Ants

The Argentine ant, Genghis Khan of the emmet world, is intolerant of other species in any area it has overrun. Due to its aggressiveness, its unrelenting persistence in the attack, and especially to its superior numbers, this insect soon overcomes even the largest ant. It does not hesitate to attack the fire ant and the agricultural ant, even though they are armed with fiery stings. When the Argentine ants attack ants many times their size, they attach themselves to the appendages of their unfortunate victims; peg them out, drawing their appendages as taut as fiddle strings. Thereupon they mount the unfortunate and securely held ant; bite off its antennae, and later decapitate it.

Woodworth[8] studied the wars between the Argentine ant and its arch enemy, the odorous house ant, *Tapinoma sessile* Say. He made some interesting observations on its battles with the Argentine ant, in which he noticed that the odor

> is produced by a liquid secretion (speaking of the ejection from the anal glands) which can be ejected from the abdomen as an appreciable drop, and which is used in its contests with the Argentine species. As long as the supply of the secretion lasts the *Tapinoma* has no difficulty in keeping the Argentine ant off, but after having put four or five Argentines out of the combat in this way finally the *Tapinoma* is put to rout and the Argentines are invariably victorious, because they always attack in sufficient numbers. We have observed many battles between these species and the *Tapinoma* is always driven away from its feeding ground and its home despoiled.

This insect has no important natural enemies in the United States, but at times it has had some interesting contests with variable results against army ants.

Since the insect will not tolerate any sick or dying ant in the nest, there can be but little hope of natural control through artificially disseminated diseases caused by virus, bacteria, protozoa, fungi, etc.

### Description of the Various Castes

It may not be amiss at this point to describe with a little more accuracy the villainness of this piece. The worker or sterile female is 2.2 to 2.8 mm long, but it may appear larger when the abdomen is extended with food. In color it varies from a light to a dark brown, with the thorax, scapes and legs somewhat lighter. The mandibles are yellowish and dentate. Often, when the worker is descending from a tree, the abdomen will appear honey-colored, due to distention of the abdomen by liquid nourishment. The worker, as its name implies, does all the work, such as excavating the nest, obtaining food, feeding the young, protecting the colony and annoying the homeowner.

The brownish queen is from 4 to 6 mm in length, and is by far the largest ant in the colony. There is usually a number of queens in one colony. One may readily demonstrate this by merely pouring a milk-bottle full of water onto a nesting site; within a short time the workers with young in their mandibles, and very often a number of queens, will emerge. Since a colony may consist of a maize of trails ramifying throughout

[8] C. W. Woodworth, *Calif. Agr. Exp. Sta. Bull.* 207, 1910.

an extensive area, the queens may number in the hundreds.

Newell found the winged queen on rare occasions in an outdoor nest in Louisiana and encountered the alate female much more frequently in artificial nests. It was his opinion that the queen mates in the nest, making wings unnecessary. The author has yet to find a winged queen in California.

Hertzer[9] notes that the queen is not a mere egg-laying machine, but takes an active part in the feeding and grooming of the young. Moreover, in this highly successful species, the queen feeds and cleans herself.

The winged male is a small-headed, big-chested nonentity who shortly after mating departs from this vale of tears. Like other gentlemen we know, he is very fond of bright lights on warm summer nights.

### Nests of the Argentine Ant

The Argentine ant has a vertical distribution from sea level to approximately 4,000 feet. Throughout its range it will be found nesting wherever there is a suitable amount of moisture in the soil, where light is excluded and where the food supply is in close proximity.

In the spring of the year the nest will often be found in open ground with small piles of excavated earth but a short distance from the nest holes. Form boards along walks, and in fact, wooden objects of any kind are preferred as nesting sites and permanent runways, as are cracks and crevices in concrete walks. The area beneath a plant infested with "ant cows" will often be honeycombed with their tunnels. The ants may be encountered in enormous numbers in and under dead and decaying stumps. During warm weather they are partial to the underarea of houses and may use the mudsills as their runways. The nest may even be established in the house proper. The queen and her following of neuters have been observed to invade the second floor of a house and to establish themselves beneath a damp rag on a kitchen sink.

The nests during the summer are usually very shallow, but 1 or 2 inches beneath the surface; on one occasion a nest was found about the roots of a tree, situated on a slope, that was more than 12 inches in depth.

In the autumn the insects aggregate into a virtual ant metropolis in which there are hundreds of queens. The huge nests may be found beneath boards, sheets of tin, buildings, etc., as well as in accumulations of dead plant material with its attendant heat of decay. The author has found the Argentine ant overwintering in enormous numbers in tunnels containing hot conduit pipes. Smith[10] noted that in northern localities this hexapod may become established in buildings, and spread from edifice to edifice, thereby avoiding the cold of winter. With the coming of spring, these colonies break up into smaller affairs consisting of one to several queens with a large number of workers all of whom migrate and establish themselves elsewhere. In fact, during the spring and summer months, an individual queen may take a stroll in the open, and upon acquiring a retinue of workers, establish her own colony.

### Means of Spreading

The Argentine ant has been distributed, mainly, by "riding the rails" in products of all kinds to widely separated parts of the country. Its spread by crawling is rather slow, and Smith found this natural spread to be a few hundred feet per year. It is often introduced into hitherto uninfested areas in balled nursery stock.

That water may also serve as a transporting medium is noted by Barber, who is quoted as follows:

[9] L. Hertzer, *Ann. Ent. Soc. Amer.*, 23: 601–609, 1930.

[10] M. R. Smith, *U.S.D.A. Circ.* 387, 1936.

Lumber, rotting trees, unrooted shrubs, cane growth, fruit vegetables and all manner of refuse contribute to the mass of matter borne on the crest of flood water, and in this the ants seek refuge and are involuntarily transported. Nature has endowed this species with a remarkable habit of self-preservation from drowning in times of floods, for when rising water floods their nests and no other means of escape are presented they cluster together and form a compact ball. The immature stages form the center of this ball, with the queens and workers as the outer portion. As the ball enlarges from the addition of other workers which have been struggling alone in the water it gradually revolves. It is kept revolving slowly by the outside workers continually striving to reach the top of the ball, thus permitting air to reach the interior. The writer has had only one opportunity of witnessing the formation of a ball of this kind. After a 5-inch rainfall several balls, none more than 2 inches in diameter, were observed. According to reliable authorities, such balls have been observed on many occasions, some of them from 6 to 8 inches in diameter. The ants in these balls disperse when they come in contact with a secure resting place, such as a floating piece of timber or land, but they have been seen to float around for hours on still water.

Steamboats and driftwood in flood waters were particularly responsible in distributing the ants along waterways in the southern states.

### The Argentine Ant and Its Environment

One of the most important limiting factors in the distribution of this species is the amount of moisture in the soil. The effect of a relative absence of soil moisture is very noticeable in the arid parts of the interior valleys of California, especially in the vicinity of Bakersfield, where the natural spread of the ant is very slow. Here one may observe the insect to be superabundant in and around the watered grounds of the home; yet, 2 or 3 feet away from this artificially moistened area, nests of the fire ant and of the agricultural ant are present, excellent proof that the Argentine ant is limited to the more humid soil. The immature stages are especially dependent upon a damp habitat.

Excessive soil moisture, on the other hand, caused, for example, by rains, will force the ants to seek shelter of some kind. Titus[11] noted that during wet weather in Louisiana, the ants constructed nests up in trees to which they had previously carried the immature forms. These nests were constructed with earth carried from the ground. Some of them were situated in forks of live oak trees, some 15 to 20 feet above the ground. The phenomenon of the ant carrying its whitish eggs, larvae and pupae up a plant or the sides of a house is a daily occurrence when one waters a garden infested with it. As was previously noted, the ants are very resistant to drowning. Smith records an ant colony situated on a post that was submerged for 3 days; after the recession of the water, the colony was found apparently unharmed. There is a great mortality of the ants during the winter months when the ants are numb with cold, and thus unable to adapt themselves to conditions caused by excessive rainfall. Rain, moreover, prevents the worker from foraging for food.

One may observe this persistent creature to walk on a small surface of water, especially when the water has been standing for a time, and has accumulated some dust on the surface. It may alternately walk and swim across this surface.

The ant becomes most numerous and most troublesome during the summer months. The rapid increase in numbers during a short stretch of hot weather is nothing short of phenomenal. In cities such as Bakersfield and Sacramento, California, where the maximum temperatures may rise well over 100 degrees F. for days at a time, this moisture-loving ant lives in the damp earth on the north side of the home or under the house itself. On such hot days it makes a pest of itself

[11] E. S. G. Titus, *U.S.D.A. Bur. Ent. Bull.* 52: 78–84, 1905.

by invading the house and foraging for moisture around the sink and bathtub.

The minimum temperature of our more northern localities is an important factor in confining the range of the Argentine ant. This to a great degree explains their absence from areas north of California and the southern states, except for isolated infestations where they live in artificially heated buildings.

Although cold is a limiting factor in its distribution, this originally tropical ant is at times remarkably resistant to low temperatures. Smith found that in protected places it may move at temperatures as low as freezing. He further states that he

> once found in a rotten log, packets of workers that were thoroughly encrusted with ice and were so stiff and motionless as to give the appearance of being dead. The temperature the night before had been 13°. When a mass of the workers was taken to a laboratory, they thawed out in an hour or so, without any apparently ill effect, and became as active as ever.

The writer, on one morning when frost covered the ground in Berkeley, California, wondered what had happened to a colony of the Argentine ant that had been under observation. Preliminary probing of the soil revealed naught of the ants. Further digging resulted in the removal of a clod of mud which had interesting potentialities. The normal mud ball is naturally entirely inanimate; yet this one conveyed a distinct sensation of vitality, and closer examination revealed that this effect was due to the slow flagellate-like movement of many appendages. The mud ball was then broken open, and the appendages were revealed as the antennae of the ants, hundreds of whom were thoroughly encrusted in the mud. The antennae were the only appendages capable of being moved by the frigid ants. These soon thawed out.

Herbert[12], on the other hand, found that the Argentine ant succumbs under artificial conditions of refrigeration if held for 24 hours at a temperature of 31° F. or in a shorter time if held at a lower temperature.

Air movements are quite a problem to the Argentine and other species of ants, and they will not be found foraging in open places on windy days. At these times they will seek shelter in protected places, such as under the loose bark of trees, beneath stones and in cracks and crevices.

According to Newell and Barber the ants become accustomed to loud noises and constant vibrations, and have been found "between and under the ties of railroad tracks over which many trains passed daily."

Many individuals have observed the seeming preference of the Argentine ant for electric outlets and switch boxes. Hackley[13] discovered large numbers of dead ants in household electrical outlets. When he turned off the current of the main switch the ants no longer came to the electrical baseboard outlet. When the current was turned on again, they came back. From this he concluded that the ants are attracted by the action of the electric current and are killed as a result. Is it possible that shelter and warmth may also be factors here?

## History of the Control of the Argentine Ant

The evolution of the ubiquitous bottle of ant sirup or ant paste was indeed a tortuous one, and it may not be amiss to lift the veil of obscurity from those men who, if they did not make the world safe from the Argentine ant, at least helped keep them out of our homes.

The first methods of curbing this creature in the United States were rather crude, and consisted of banding the legs of furniture with tape soaked in corrosive sublimate, or using the still prev-

[12] F. B. Herbert, *Jour. Econ. Entom.*, 25: 832–833, 1932.

[13] R. E. Hackley, *Pests*, 8: 16–17, 1940.

alent ant powders, or by trapping and fumigating the nests of the ants. These methods left much to be desired, and entomologists first began to settle the fate of the Argentine ant when they interested themselves in poison baits.

Arsenic is our best-known poison, and when ants were observed to feed upon sweets, a bait of arsenic and a sugary material was naturally suggested. That the bait method of control is not a new one is revealed by Roark[14], who quotes Worlidge ("System Agricultural, the Mystery of Husbandry Discovered," 1669) as follows:

> Also you may make boxes of Cards or Pasteboard pierced full of holes with a bodkin, into which boxes put the powder of Arsenick mingled with a little Honey. Hang these boxes on the tree, and they will destroy them, make not the holes so large that a Bee may not enter lest it destroy them.

Newell[15], of the U. S. Bureau of Entomology, first pronounced the following important consideration in the control of the Argentine ant, namely, that the poison must be

> one which will destroy larvae and workers, as well as queens, within the colony. To meet this requirement the poison must be fatal but must act so slowly when contained within the insect stomach that it will not kill the foraging workers ere they can transport it to the nest and there deliver it to other members of the colony.

He had but indifferent success with a mixture of lead arsenate and sugar and honey, and lead arsenate and honey alone. He was also one of the first to announce the repellent effect of arsenical sirups, and with reference to this, states, "Our experiments have shown that solutions of sugar or molasses containing a small percentage of arsenic can be used to 'drive' the ants from a room which the foragers persist in visiting." He moreover suggested the use of one of the first weak arsenical solutions, namely, "White arsenic, ½ gram; cane sugar, 20 grams; water, 100 cc."

At this same time, Newell notes that C. P. Lounsbury, entomologist of the Department of Agriculture at Cape Town, South Africa, succeeded "in repelling the Argentine ants from residences there by the use of very similar mixtures. Those most frequently used by Professor Lounsbury are Cooper's dip and Golden Syrup, equal parts, and a mixture of marmalade, sugar and arsenite of soda." Here mention is made for the first time of the use of sodium arsenite, the key to the control problem.

In 1905, Titus discovered the Argentine ant in Ontario, California. Two or three years later, Woodworth, of the University of California, visited Louisiana, where he studied Newell's work on the Argentine ant. In 1910, in Bulletin 207 of the California Agricultural Experiment Station, Woodworth recommended reducing the arsenic between ¼ to ⅛ of 1 per cent., but he did not state what form of arsenic he used. Nickels,[16] who worked with Woodworth, stated he used ¼ to ⅛ per cent. sodium arsenite in a sugar sirup. Thus it was Woodworth who definitely recommended for the first time the use of a weak solution of sodium arsenite.

Wilmon and Newell, in 1913, once again emphasized the fact that sweetened arsenical mixtures act as repellents, and were driving the colonies away instead of exterminating them.

In 1916, Barber, of the U. S. Bureau of Entomology, improved Woodworth's formula by reducing the amount of arsenic in solution. W. E. Cross, a chemist in the Sugar Experiment Station in Louisiana who worked with Barber on the ant sirup, was largely responsible for the preparation of the poison which subsequently was called the Government

[14] R. C. Roark, *Soap*, 11: 101, 1935.

[15] W. Newell, *Jour. Econ. Entom.*, 2: 174–192, 1909.

[16] L. J. Nickels, *Jour. Econ. Entom.*, 4: 353–358, 1911.

Argentine ant formula. He made a careful study of the chemical aspects of the ant sirup and was the one to suggest that

> the addition of a small quantity of tartaric acid to the sugar sirup before adding the sodium arsenite will produce a greater inversion of the sucrose, thus lessening the danger of crystallization and will neutralize the alkalinity of the sodium arsenite, preventing decomposition. If a slight acid reaction is obtained the sirup will keep indefinitely.

R. S. Woglum and A. D. Borden[17] modified the Barber-Cross formula by reducing the amount of sugar and increasing the amount of honey. This resulted in a further reduction of crystallization in the sirup. The poison bait was kept from fermenting too quickly through the addition of benzoate of soda. And with this contribution we have the Government Argentine ant formula which with slight modifications is in use to-day.

In 1924 Smith[18] and other members of the Mississippi State Plant Board succeeded, with the use of the Government Argentine ant formula, in exterminating an infestation of the ant from 1½ blocks in Fayette, Mississippi. This was the first town in the world from which the Argentine ant had been eradicated. Smith in 1936 disclosed that other towns in Mississippi had succeeded in eradicating the pests. In these instances the poisoned arsenical sirup actually exterminated rather than merely repelled the ant.

In many areas of California, particularly where intensive control is undertaken in citrus orchards, great reduction of the ant results. In other areas, control with the Government Argentine ant formula is extremely slow, and during the summer, is apparently non-existent. In such localities the ant sirup is placed around the home, where it is used as a "bribe" to inveigle the ant into feeding *outside* the house.

The greatest innovation in the control of the Argentine ant since the advent of the Government formula was the introduction of thallous sulfate (commercially called thallium sulfate) as the toxic ingredient in the ant sirup. Any individual who has used the arsenical and the thallous formulas soon becomes cognizant of the much greater effectiveness of the thallous sulfate sirup. The reasons for this increased effectiveness have not been investigated, but it is believed to be due to the fact that the Argentine ant "takes" better to the poison, and that the poison acts more quickly upon it. According to H. Hartnack,[19] a pest control operator in Chicago, he suggested the use of thallous sulfate as an ant poison to C. H. Popenoe, and with the latter evolved a formula for the control of Pharaoh's ant, *Monomorium pharaonis* (L.). Popenoe[20] published a note on this, and the sirup was subsequently used in the control of the Argentine ant. Some states prohibit the use of thallous sulfate, since it has no simple antidote.

## Reasons for the Success of the Argentine Ant

What are some of the factors that have lifted this hexapod alien from the ranks of obscurity to public prominence as "Ant No. 1"?

(1) Unlike ants of most other species, the Argentine ants, even from widely separated colonies, are friendly to one another. The queens are likewise so.

(2) In an infested area it will be found that the widely separated runways of the ants eventually anastamose. Moreover, there are a great number of queens in an infested area who have a high reproductive potential. As a con-

[17] R. S. Woglum and A. D. Borden, *U.S.D.A. Bull.* 965, 1921.

[18] M. R. Smith, *Jour. Econ. Entom.*, 17: 603–604, 1924.

[19] H. Hartnack, "202 Common Household Pests," 182–183, 1939.

[20] C. H. Popenoe, SCIENCE, 64: 525, 1926.

sequence there arises an enormous number of individuals, with resultant huge and powerful colonies.

(3) The ant is extremely adaptable, and nests in a great variety of situations.

(4) There is usually no dearth of food for the omnivorous worker. The worker, moreover, is persistent, courageous and tenacious. These qualities plus their great numbers result in the defeat of practically every insect that opposes them.

(5) The female is not a mere egg-laying machine, but partakes in the grooming and feeding of the young. Almost always she mates in the nest and is therefore not subject to the perils that attend the mating flight of other species of ants. The mated female can initiate a new colony merely by walking off with a following of workers.

(6) There is no important natural enemy of the ant in the United States.

(7) Finally, they are readily distributed through natural and man-made facilities.

With apologies to Aesop and with the kind permission of the reader, may we moralize that the traits responsible for the great success of the Argentine ant in this country are almost identical with those qualities so prominent in our outstanding bipedal immigrants. These qualities are adaptability, courage, persistence and the capacity to cooperate. Fortunately for man, this ant is lacking in one prominent characteristic, intelligence!

## THE SEARCH FOR UNITY

If we are to have a durable peace after the war, if out of the wreckage of the present a new kind of cooperative life is to be built on a global scale, the part that science and advancing knowledge will play must not be overlooked. For although wars and economic rivalries may for longer or shorter periods isolate nations and split them up into separate units, the process is never complete because the intellectual life of the world, as far as science and learning are concerned, is internationalized, and whether we wish it or not an indelible pattern of unity has been woven into the society of mankind.

There is not an area of activity in which this can not be illustrated. An American soldier wounded on a battlefield in the Far East owes his life to the Japanese scientist, Kitasato, who isolated the bacillus of tetanus. A Russian soldier saved by a blood transfusion is indebted to Landsteiner, an Austrian. A German soldier is shielded from typhoid fever with the help of a Russian, Metchnikoff. A Dutch marine in the East Indies is protected from malaria because of the experiments of an Italian, Grassi; while a British aviator in North Africa escapes death from surgical infection because a Frenchman, Pasteur, and a German, Koch, elaborated a new technique.

In peace as in war we are all of us the beneficiaries of contributions to knowledge made by every nation in the world. Our children are guarded from diphtheria by what a Japanese and a German did; they are protected from smallpox by an Englishman's work; they are saved from rabies because of a Frenchman; they are cured of pellagra through the researches of an Austrian. From birth to death they are surrounded by an invisible host—the spirits of men who never thought in terms of flags or boundary lines and who never served a lesser loyalty than the welfare of mankind. The best that every individual or group has produced anywhere in the world has always been available to serve the race of men, regardless of nation or color.—*Raymond B. Fosdick in The Rockefeller Foundation Review for 1941.*

# CULTURE AND HUMAN BEHAVIOR

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THE history of social science reveals a shifting of interest from one aspect of social behavior to another. In each successive change there has been a tendency to overemphasize the new approach, discounting even the most valid conclusions contributed by the previously popular point of view.

At one time in the history of social theory, social scientists placed a heavily disproportionate emphasis upon the rôle of instinct in social behavior. Many acts now known to be the direct outcome of long and insistent training were held to be the expressions of an instinct. This position could not be maintained in the face of the mounting evidence for cultural relativity which anthropologists were able to compile. Abandoning the instinct theory of culture, social scientists began to focus their attention upon the varying kinds of behavior which human beings exhibit. Thus, to-day, many anthropologists are concentrating upon the relativity of culture, demonstrating the wide range of variation in human learned behavior. Other anthropologists, primarily interested in the topics of culture change and acculturation, are accumulating large masses of factual evidence on such topics as invention and diffusion. Others, again, are examining the relationship between environment and culture, centering their interest upon the conditioning effect of the environment. Still others are concentrating on the transmission of culture, *i.e.*, the process by which a child learns to become a member of his society.

Anthropology is not the only discipline to center its interest around the topic of human learning. Culture historians trace changes in the customs of specific groups as they occurred over centuries of experience. Sociologists attempt to capture the trends of changing behavior norms. Other sociologists are studying societal evolution; they seek to outline the steps in a process of continuous learning which has lasted nearly two million years. To the educator human learning has always been of paramount interest. His concern is inevitably with the process of transmitting culture to the incoming members of the society. Psychologists as well are interested in the topic of human learning and some of them, indeed, have taken for their specific interest an analysis of the learning process. However, despite this universal interest in the topic of human learning, there is little coordination between the various investigations in their attack upon this problem.

For the development of a science of human behavior it seems important to concentrate specifically upon the learning process and to coordinate the tools from those disciplines which have something to contribute. Only in this way can an effective attack be made upon this exceedingly vital aspect of human behavior. The importance of understanding the human learning process can scarcely be overestimated. Without such an understanding social science predictions most probably will fail and, if it lacks predictive power, social science will remain a pseudo-science whose research workers will be regarded as parasitic eccentrics in the society which harbors them.

The human learning process is governed by rules or principles. The more

basic of these principles are well known to psychologists.[1] The essential elements of learning are (1) *drive,* (2) *response,* (3) *cue* and (4) *reward.* The *drive*[2] is the motivation which stimulates a person to act. People are in an almost constant state of unfulfilled desire. Indeed, one of the characteristics serving to distinguish between living and nonliving objects is this very incentive to action which finds its source of energy within the organism. It seems to be an unquestioned fact of human experience that mere living involves a constant striving for as yet ungratified longings and cravings. Drives may be either innate or acquired. Hunger, thirst and pain are examples of innate drives; anxiety and anger are examples of acquired or learned drives. *Cues*[3] give direction and orientation to responses. Cues may be provided by sense-organ stimulation from outside or by reactions of the organism. The *response* consists of acts, *i.e.,* what the organism does. Generally speaking the response may be considered to consist of a goal response and a series of instrumental acts. The goal response is the act immediately followed by reward; the instrumental acts are those preceding the goal response. If the response succeeds in bringing about a diminution in the intensity of the drive, the result is *rewarding.* Reward reinforces the connection between the cues and the response; an increment of learning takes place. Whenever the same drive and cues are again present, the same response will be more likely to occur. This is known as the *principle of reinforcement.* If, however, the response fails to be rewarded, then the bond between the cues and the response becomes weaker. Repetition of a response without reward leads finally to an extinction of the cue-response connections and the response fails to occur on subsequent occasions.

For human beings learning continues throughout life. New responses are learned and old ones abandoned. While habits may lie dormant for a time if they are not practiced, responses do not persist if they are tried over and over again without success. This means that customs which are not rewarding to the persons who practice them will become progressively weaker and will eventually disappear. In other words the persistence of customs depends upon their rewarding value. From this standpoint culture consists of behavior which is constantly being reinforced; it is functionally integrated with human motivation and reward. Culture is neither self-perpetuating nor self-destroying, nor are customs arbitrarily accepted or rejected; rather, they are habits strengthened by rewards or weakened by a lack of them.

Social theorists will immediately question the possibility of determining what drives are operating in any given instance. When the actions of a specific person are observed it becomes difficult to determine the drive which motivates his behavior. If a person is observed eating a meal we would probably not be too far wrong in assuming that he is motivated by hunger as modified by past learning, *i.e.,* by an acquired appetite

[1] Perhaps the most acceptable statement of these principles for anthropologists is that of N. E. Miller and J. Dollard in their recent volume, "Social Learning and Imitation" (New Haven, 1941). For an extensive account of learning principles the reader is referred to their publication. See also Clark Hull's forthcoming book, "Principles of Behavior," and "Becoming a Kwoma" by J. W. M. Whiting (New Haven, 1941).

[2] Learning always takes place under certain internal conditions in addition to drive, such as habit structure, capacity for motor behavior, and susceptibility to sensory stimulation. Important as these conditions are for any thorough analysis of a given person's behavior they will not be considered in this paper.

[3] The cue is a stimulus whose primary function is the direction of behavior, in contrast to drive which is a stimulus whose primary function is to motivate the response.

for the foods which constitute his meal. On the other hand, if he is observed attending a church service, hypotheses about his motives are likely to be the wildest kinds of guesses. More information about the person would help to substantiate some guesses and to eliminate others. Ultimately, with sufficient data concerning his life history brought to light, it might be determined that his behavior stems primarily from an acquired drive of anxiety, or perhaps a desire for prestige in his community.

If the actions of a person in a society other than our own are observed it becomes even more difficult to determine his motives. A Fijian, for example, might be observed to dye his hair black or to avoid his brother's wife. It would be a mistake to assume that the native wishes to do these things for the same reason that we would want to perform similar acts in our own society. The drives prompting his behavior may be quite different from those which would lead us to similar behavior. Only an intensive investigation will lead to the discovery of why he wants to act in this way. But the difficulty of determining the drives which operate in a specific instance does not in itself negate the importance of recognizing that behavior is motivated by drives. It points rather toward a research problem, the solution of which will add substantially to the understanding of human behavior. It is likely that operational definitions of drives will solve this problem. If drives are defined in terms of the conditions which produce them, it is not difficult to determine what drives are operating in a given situation. Hunger, for example, may be defined as a drive which increases in intensity with the number of hours of food deprivation. By discovering the length of time a person has gone without food it is possible, on this basis, to estimate the strength of his hunger drive.

Many drives are common to mankind; they accompany human life wherever it exists. Some of these drives are universal because they are a part of the natural equipment of the human organism; others are universal because they are always acquired by people during their life experiences. An exhaustive list of these universal drives has not yet been developed. Among the innate drives may be mentioned hunger, thirst, air-hunger, fatigue, sex, pain-avoidance, heat and cold avoidance and the several drives of elimination. Among the drives universally acquired through experience are anxiety or fear, anger, love, various appetites and disgusts, and probably a desire for children, a wish to be healthy and a desire for prestige. Since acquired drives are learned it is likely that their intensity varies somewhat from person to person and from society to society. This is a factual question which can be answered only by careful investigation. Nor can a list of universal drives be padded by hasty generalization from any one or a few societies. Sexual jealousy, for example, which seems so powerful an incentive to action in our society may be found to be relatively weak or even absent for the members of other societies where an entirely different set of sex mores prevail and where the training of the child is quite foreign to our own. Nevertheless, the fact that many conditions of life are common to all societies leads to the assumption that a considerable number of acquired drives are universal.

Learning always occurs in the context of a specific situation; human behavior always takes place under certain external conditions. The learning situation is as important to an understanding of the process of human learning as are the principles which have been briefly outlined above. For human beings learning situations and the conditions which compose them are many and varied. Each person lives as a member of a society

which has its own distinctive social structure and culture, and moves about on a portion of the earth's crust which has its own fauna and flora, inorganic resources, topography and climate. In brief, any human being learns in a situation which consists of all the objects, events, and energies of his immediate environment.

When a social scientist presents a monograph upon a particular society or community he presents a description of the people, the environment in which they live, their material apparatus, their social structure, their language, and their culture. From one point of view, the ethnographer presents a description of the conditions which compose the learning situations of any member of that society. Such facts as density of population, productive power of the land, and the stage of their arts and crafts are widely recognized as factors bearing a significant relationship to the behavior of the members of a society. Of importance also are the minerals, flora and fauna of their environment; the categories, groups, and institutions, constituting the structure of the society; the habits of speech and thought; the manual skills and social techniques composing their culture. These and other conditions which the ethnographer describes, are the constituent elements of any learning situation in which a member of that society finds himself throughout his lifetime. Under these conditions the people who compose that society learn to behave in certain ways; under these conditions their responses are strengthened and persist, or are weakened and disappear. The description given by the ethnographer might thus be termed his approximation to the sum total of the conditions composing any learning situation in that society.

From another point of view, an ethnographer's description of social structure, language, culture, and technology might be considered the result of a long history of learning on the part of the ancestors of the present members of the society. During the historical period forming the background of that society, millions upon millions of responses have been made by its members under stimulation from their drives. Some of these were successful under the conditions of their era, were reinforced, and were learned. Others that were tried, failed to be rewarded and were not accepted. As time passed conditions changed and responses once rewarding were no longer successful. New responses were tried and the more successful of these became accepted. During this process of societal learning, adjustments were made to the conditions set by group life as well as by the environment. Behavior patterns which might otherwise have been rewarding failed because they interfered with other and more heavily rewarded responses. The hungry men who clouted other members of society over the head to take their food were themselves set upon and punished. Through the centuries, people learned that such interference with their neighbors was not advantageous; limits were set to ingroup aggression. In the long run responses conducive to the welfare of the group were the most heavily rewarded and they persisted; many actions which were more immediately effective in reducing the drives of individuals were found to be less rewarding under conditions of group life, and were abandoned. Acquired drives and the responses which reward them reveal at any given point in time along the societal life-line the results of past learning. This process of learning still continues in each society. Each member of the society learns anew under the conditions of his environment, an important part of which consists of people whose heritage from the past is a whole series of time-tested behavior patterns.

While many of the conditions com-

posing learning situations vary considerably from society to society, others are universal. The force of gravity, inertia and friction, the changes in light intensity, temperature, humidity, atmospheric pressure, and the like everywhere accompany human life. To be sure there are variations in some of these conditions from society to society. Thus, light and dark varies with the latitude, some people are subjected to extreme variation in heat and cold, and so on. Nevertheless they are conditions universal to mankind. Also significant to all people are the conditions presented by human physiology. In all societies women menstruate, conceive, and give birth to their young; people become sick, grow old, and die. Such events as these supply a host of conditions common to all mankind. In every society, moreover, there are aspects of social structure and culture, products of societal evolution, which are common to all societies. Such, for example, are categorical differentiations based on sex and age, the basic family group, the use of language; all societies forbid incest, ingroup murder, theft and rape; and all societies have their methods of obtaining and preparing food and drink, techniques for the manufacture of material goods, and accepted ways of obtaining sexual gratification.

The amount of detail into which an ethnographer can go in describing the life conditions of the society under his observation is limitless. This becomes at once clear if the difficulty of describing a single learning situation be envisaged. Any given situation could presumably be described in terms of all its various conditions, but such a description would be almost endless, since the details which might be included are exceedingly numerous. From the standpoint of human learning, however, it is not necessary to ferret out the very last detail of a given learning situation. It is important only to consider those conditions which are relevant to the learning process. If a child is learning to nurse from a bottle, for example, such conditions as the fullness of the moon, the time of year, and the number of chairs in the room are probably irrelevant. On the other hand the shape and appearance of the bottle, the words uttered by the mother, and the taste of the milk are likely to be of paramount importance.

If it is true, as it seems to be, that some conditions are more important than others from the standpoint of human learning, by what criteria can one determine the relative importance of these conditions? The relevance of conditions to learning depends upon their relationship to the four crucial factors of drive, cue, response, and reward. In the example given above, it is highly doubtful that the fullness of the moon, the time of year, and the number of chairs in the room bear a significant relationship either to the child's drive or to its response, nor do they directly furnish cues or appreciably affect the reward. Moreover, these conditions are not likely to remain the same whenever the child is nursed. By contrast the shape and appearance of the bottle, the mother's speech and the taste of the milk all consistently accompany nursing and probably perform at least one significant function, namely, that of providing the child with distinctive cues.

The conditions composing a situation may be important as the source of cues to which the response becomes attached during learning. A person receives many of his cues from his environment. The importance of conditions in providing cues is perhaps most clearly brought out by contrasting different learning situations. For example, people may learn to react with friendly approach tendencies in situations where members of their own society furnish the primary cues for their behavior. If

the same people find themselves in a situation where members of another society are present, the more similar these foreigners are to the members of their own society, the greater will be the tendency to react with friendly approach tendencies. Thus if the foreigners are of a similar physical type, wear similar clothing, exhibit similar haircuts, and the like, the tendency to react with friendly approach tendencies will be exceedingly strong. The difficulty in discrimination thereby arising depends upon the similarity of the primary source of the cues in the two situations. If the foreigners are deadly enemies, the mistake is likely to be very costly. Faced with such a difficulty many people have learned to differentiate themselves from their dangerous neighbors, thus facilitating cue-discrimination. Devices serving this function are, for example, special types of clothing, different forms of headdress, and tattooing. Language affords another device: those who belong to the ingroup may be designated by a word such as "friend," whereas those belonging to the outgroup may be given a term such as "enemy." Such words are responses with specific learned cue-value. The use of such terms permits rapid discrimination between conditions which are otherwise quite similar as sources of cues.

Quite apart from their relevance as sources for cues, the conditions of a learning situation may be important for learning because they affect the drive. Indeed, external conditions may be the primary basis of drive stimulation. A very loud sound, a bright light, cold air, the heat of the sun's rays, a knife pressing into the skin, or the pressure of a heavy weight are examples of external conditions which may produce internal stimuli of drive value. Acquired drives are often evoked by external stimuli: danger signals evoke anxiety, taunts, anger, and the death of a loved one grief. Somewhat more indirectly the intensity of drives already operating may be increased because of the external conditions. Thus, lack of food, air, water, or a suitable sex-object will result in an increase in the intensity of internal drives.

In direct contrast to the rôle of conditions in increasing the intensity of a drive is the relationship which they bear to reward. Conditions may serve to reduce the intensity of the drive and thus produce a rewarding state of affairs. A person stimulated by a loud sound is rewarded when the noise ceases; a person driven by the pain of a knife pressing into the skin is rewarded when the knife is removed; a thirsty person finds his drive intensity reduced when water trickles into his mouth and throat; anxiety is reduced when the danger signal disappears. Learning is primarily dependent upon the rewarding function of conditions for, unless a reduction in drive-intensity takes place, learning does not occur.

The conditions may also be important to learning because they limit the kinds of responses which a person can make. This is most obvious in the case of a man bound hand and foot to an electric chair or placed in a padded cell. But external conditions other than bonds and jails restrict responses. A primary instance is gravity, a limiting condition which man is never able to escape. Because of gravity he can jump only so high, finds himself unable to fly without mechanical apparatus, and so on. Responses are also limited by the fact that of all the things which might conceivably enter into human behavior only a few may exist in the surrounding environment. The house which man may learn to build as a means of providing warmth and shelter in a frigid climate can only be constructed of the available materials. People can not learn to make pottery if there is no clay. Where animals which

can be domesticated do not exist, no pastoral culture can develop. Furthermore, not all the things which the environment actually contains may be available at a specific stage of development. The techniques which have been developed in material culture may not provide for the extraction of certain materials which would be available with different and more advanced technological processes. Iron may be extracted from certain ores, but if the technological processes of smelting and the like are unknown, the iron may remain so hidden that for all practical human purposes it might just as well not exist in the environment. Until such processes are learned, or until iron is introduced from another society, responses which involve the utilization of iron can not be learned.

From this analysis it becomes clear that external conditions are relevant to the process of human learning if they provide cues, affect drive stimulation, or govern the responses which the organism can make. Implicit in this analysis is the assumption that learning only takes place in a situation which poses a problem. A problem arises when the situation is not immediately rewarding, *i.e.*, when the conditions do not permit a successful goal response. By this definition a problem consists in learning how to change a nonrewarding situation into a rewarding one. It is the function of behavior to make this change, thus solving the problem. If the situation is immediately rewarding, no problem exists. The drive is reduced without intermediate instrumental responses and learning does not occur. If the situation is *not* immediately rewarding then a problem exists. If a response is then made which solves the problem, *i.e.*, changes the nonrewarding situation into a rewarding one, learning occurs. Learned behavior therefore consists of problem-solutions.

The nature of the drive immediately marks out and specifies in advance the types of conditions which will permit reduction in the intensity of that drive. Thirst, for example, can only be diminished if the situation provides a suitable liquid. Hunger, likewise, demands certain specific conditions for its reduction. Similarly, fatigue, sex, and pain-avoidance drives mark out a limited number of rewarding conditions. Conditions vary in their capacity for drive reduction within the band of tolerance set by the drive-specifications. Though a person may be able to get some rest sitting in the seat of a cross-country bus, his fatigue drive will be more adequately reduced if he can stretch out in a comfortable bed. The specifications set by a drive thus rank conditions in a hierarchy in accordance with their drive-reducing value. If the specifications are known it is possible to predict which one of the experienced situations will be preferred.

In real life basic and innate drives seldom operate in their virgin state, unelaborated by past learning. People generally respond under the stimulation of basic drives as they have been modified by previous rewarding experiences. Acquired drives set more elaborate specifications than do the basic and innate drives. The desiderata imposed by thirst or hunger, for example, are less exacting and complex than those set by an acquired appetite for French wine or Swedish cooking. Those acquired drives which motivate instrumental responses leading to drive satisfaction are especially likely to set elaborate specifications. As drive-specifications become more detailed, the number of possible rewarding conditions decreases. An example from technology will suffice to clarify this point. If a man desires a receptacle, that is, something which will hold something else, the number of possible rewarding conditions is great. If, however, the drive-specifications are more complete and detailed

the number of possible rewarding conditions is greatly limited. If he wishes a receptacle that will hold water and will, at the same time resist fire, the number of possible conditions which permit the solutions to his problem is severely restricted. This is a well-known principle in modern technology. Sometimes, indeed, the specifications are so precise and detailed in the manufacturing processes of to-day that it is possible to devise only one way of achieving the desired result.

It is with respect to acquired drives that the advantage of knowing the specifications which they set becomes most apparent. Only if the drive-specifications are known can one adequately identify acquired drives. The desire to have children in one society can only be compared or contrasted with a similar desire in another society if their respective specifications are known. In one society it may be of paramount importance that the child born be a boy, that it be born in wedlock, and that it show no blemish on its skin. In a second society the drive-specifications may be quite different. Here the preferred child may be a girl, legitimacy may not depend on wedlock, and birthmarks may be greeted with approval.

Given a certain set of drive-specifications, the response which will be successful is one that so changes the conditions of the situation that a rewarding state of affairs is reached. The kinds of response which will be rewarded, therefore, depend upon the change in conditions required by the drive-specifications. Sometimes this change is relatively simple and a response is at hand to take care of the problem. A baby is born into an atmosphere of air. Once the baby breathes, air is drawn into his lungs. Conditions are such that the simple response of breathing does not fail. To attain a rewarding state of affairs is easy; the problem is solved by the breathing mechanism. But if circumstances are altered and the baby falls into the lake, the same mechanism sucks water into his lungs. The response fails dismally. Such a change in conditions poses a more difficult problem. Some new response must be made if he is to get air into his lungs instead of water. In solving this problem swimmers learn to hold their breath for a short time and then so to twist their bodies and move their hands and feet that they come up for air. Modern technology provides devices which permit a portion of the air to be taken beneath the water so that breathing can continue. Diving suits and bells, submarines, and the like are solutions to the problem imposed by the conditions for breathing that man finds under water.

In order to be effective in changing conditions, the response must conform to the requirements imposed by the laws governing such changes. An attempt to drink water out of a sieve will fail. The same act, if a cup is used, will be successful. An attempt to blow out an acetylene torch which is burning the skin will not be followed by reward. The same act, however, will successfully snuff out a match which is too near the finger. The success or failure of a given act in bringing reward thus depends upon its effectiveness in changing the conditions. But what are the laws which govern the effects of responses upon conditions? If these laws are known, together with the drive-specifications and the immediate state of the conditions, it will be possible to predict what responses will be successful and hence can be rewarded.

Laws govern changes in types or classes of conditions. Each specific learning situation is different from all others. The identical constellation of conditions probably never recurs exactly on two different occasions or for two different persons. But while par-

ticular conditions are never precisely duplicated, types of conditions are repeated both spatially and temporally. These types depend for their definition and recognition upon the abstraction of certain characteristics. Thus one bit of metal may be classed with another bit of metal as of the type *iron,* because of certain characteristics which they both share. For the purpose of identifying these two bits of metal as iron, the peculiar and individual characteristics of each bit are disregarded. The arrangement of one crowbar placed against a stone is classed with that of a digging stick placed against a block of wood as being of the type *lever.* The significant characteristic in this instance is the pattern of arrangement, *i.e.,* the position of the bar or digging stick with respect to the stone or wooden fulcrum; other characteristics are ignored. The motion of a falling stone is classed with any other moving body whose velocity is increasing positively on the basis of the type of motion, in this case *acceleration,* which they have in common.

Types of substance, pattern, and motion have been the basic subject-matter of science. Scientific laws are the principles governing the relationships between established types. The existence of a large body of knowledge concerning the principles governing the types already established by the various sciences may well be of enormous assistance to the study of the part played by conditions in the learning process. It seems desirable, at the outset at least, to examine learning conditions in the frames of reference provided by the existing sciences. While any grouping of the various sciences must be arbitrary from a logical standpoint, conditions are classified here into the following divisions: (1) those types of conditions whose laws are being developed by physics and chemistry will be termed physico-chemical conditions; (2) those types of conditions whose laws are being developed by biology and physiology will be termed bio-physiological conditions; and (3) those types of conditions whose principles of relationship are being developed by the social sciences will be termed psycho-social conditions.

Physico-chemical conditions consist of types of substance, pattern, and motion defined in certain characteristic ways. Substances, for example, are typed in physics and chemistry by such characteristics as density, mass, tensile strength, atomic and molecular structure, acidity, melting point, and the like. All known substances may be typed in physical terms, while only a few inert masses escape refined classification into chemical types. In other words both organic and inorganic substances may be defined in physico-chemical terms as condition-types. Physics and chemistry thus classify into common types such noticeably dissimilar objects as human beings, trees, lumps of earth, and billiard balls. Whenever a problem-solution demands effective changes in the physico-chemical condition-types of the situation, the responses must be in adjustment to physico-chemical laws.

Bio-physiological conditions consist of types defined according to different characteristics. Substances, for example, are classified into types by biology and physiology on the basis of such traits as growth, metabolism, cellular and anatomical structure, and the like. Biophysiology deals only with organic conditions; all nonliving substances are excluded. Whenever responses must deal with bio-physiological condition-types, they must be in adjustment to biophysiological laws if they are to be effective. Thus if drive-specifications demand a change in the physiological state of the human organism, responses will be successful if they conform to the laws governing such a change. A person ill

with pneumonia, for example, can only get well by following the rules set by physiology as effective in assisting a return to health.

Psycho-social conditions include a still narrower range of phenomena. Psychology types only the higher order of mammals and the social sciences restrict their types to human beings. Social anthropology has gone far toward establishing types of conditions within the psycho-social realm. These condition-types are conveniently described in terms of social structure and culture. The social structure of a society has to do with the units which compose the society and the relationship between them. The persons who compose a society may be typed as members of categories and groups. A person belongs to a category if he shares with other persons some significant characteristic which is correlated with his responses. The trait of sex defines such categories for every known human society. Other characteristics used as the basis for categories are age, kinship, pregnancy, and the like. Groups differ from categories in that they are organized. A universal group for the human society is the family. The social clique, the functional unit of social classes in our own society, is another example.

Culture consists of traditional ways of solving problems. Some problem-solving responses are common to certain categories, and others to certain groups. In describing the culture of a community in the United States, for example, the social anthropologist would determine the distribution of culture by the categories and groups to which the persons of the community belonged. Within that community the effectiveness of responses in changing psycho-social conditions depends upon knowing what responses other people will make. The prediction of what other people will do in response to one's own behavior is made possible by a knowledge of the categories and groups within the society. Thus, for example, a person seeking advice about how to get well from an infection can predict that he will be more successful if he consults a doctor rather than a lawyer.

By casting types of conditions into the framework of the sciences which deal with them, it is possible to specify the laws which govern the effects of behavior on those conditions and to predict in advance the kinds of responses which will fit the drive-specifications. Sometimes, however, a change in the conditions occurs following responses which have no, or very little, direct relationship to the responses. This permits the reinforcement of nonfunctional responses. Because of this it is possible for magic and ritual to be rewarded. Instances of this chance reinforcement abound in life experience. Control of the weather is a famous example. The rainmaker carries out a procedure which is supposed to bring rain; sometimes shortly thereafter rain actually falls. The magical behavior which preceded the rainfall is rewarded.

A few examples will clarify this problem-solving aspect of behavior. When a hungry, thirsty baby sucks at the nipple of a nursing bottle, he pulls milk into his mouth and then swallows it. This change in the situation reduces the baby's drives of hunger and thirst. Learning principles tell us the effect of this event on the future behavior of the baby. Since his behavior is rewarded the cue-response connections are strengthened and an increment of learning takes place. The next time a similar situation is presented to him the sucking response will be more likely to occur than before. To understand fully this sample of learning, however, it is important to know just how the sucking response happens to be rewarded. Had the baby been driven by pain produced

by a pin sticking into its leg, instead of by hunger and thirst, the sucking response would not have been rewarding. Sucking fulfills the drive-specifications set by hunger and thirst, but not those resulting from a pin sticking into the leg. The response also conforms to the requirements set by the conditions. By suction the milk is pulled out of the bottle and into the child's mouth. The conditions happen to be such that sucking at the nipple is successful in solving this problem. If there were no milk in the bottle, if the nipple were impervious to milk or so rigid that the baby could not squeeze it with his tongue and gums, the response would fail. In this latter case the conditions would impose requirements upon the behavior of the child which would not be met by the sucking response. It will be noted that the condition-types changed by the response in this example fall in the physico-chemical realm. That is to say the requirements of the problem solved by the behavior can be described in physico-chemical terms. If, however, the situation were different other kinds of requirements might be imposed upon the child's behavior. Such would be the case, for example, if part of the baby's problem were to bring the bottle within reach of his hands and mouth. The solution to this problem might be to cry —a response dependent upon psycho-social condition-types for its success. The effectiveness of crying in changing the situation will depend upon whether or not he is heard by a nurse who has learned to respond to his cries by bringing the bottle to him.

As another example, the problem of changing the position of a heavy stone may be considered. This problem can only be solved by some response which conforms to the physical laws governing the motion of masses. Yelling at the stone, calling to it, spitting on it, and many thousands of other possible responses will fail. Why? Because to move the position of a heavy stone requires the application to it of a pressure greater than its own weight. If the person is strong enough the stone may be moved by lifting, pulling, or pushing it by hand. Such responses, however, require considerable effort and, therefore, the drive to move the stone must be greater than the counter-drive to avoid fatigue. The stone can be more easily moved by using a lever. Once this solution is tried, it will be preferred if it is easier to procure a lever and then use it, than it is to lift, pull, or push the stone.

If, instead of a stone, a person wishes to bring a wild pig to the village from the forest his problem is more complicated. Though the pig may weigh the same as the stone, the former differs from the latter in that it can move of its own volition. Conceivably the fact that the pig can move by itself might be turned to good account. The pig might be lured to the village. Whether or not this will be successful depends upon the laws governing the behavior of wild pigs. If the pig is hungry enough and if its tendency to avoid human beings is not too strong to overcome the tendency to approach food, the hunter could drag food in front of the pig and thus entice it to his village. Another way of solving the problem is to nullify the requirements imposed by the way in which animals behave. This can be done by rendering the pig powerless to move by itself. Thus the hunter might lure the pig into some kind of trap (one which the pig will not have a strong tendency to avoid) and then truss its legs in such a way that it can not move. Or he could poison the pig, render it unconscious with a blow, or kill it. Such responses change the conditions to the extent that the pig can now be treated exactly like a stone. The conditions determining the successfulness of the hunter's response have been changed.

The requirements of his problem now permit responses which succeeded in moving a stone to be effective in moving a pig.

If a warrior wishes to bring home the body of an enemy human being, instead of a pig, his behavior must conform to still more complex requirements. He is dealing not only with a heavy mass like the stone, not only with an animal which can move of its own volition and can be dangerous to his welfare like the pig, but also with an animal who is a member of a society. As a member of another society, the enemy is likely to have comrades-in-arms who will come to his assistance. To deal successfully with the problem, therefore, the warrior must make responses which will cope adequately with the complications arising out of the position of his enemy in an alien society. Requirements from the psycho-social realm are added to those from the bio-physiological and physico-chemical to which his behavior must conform if his response is to be successful. In adjustment to these new requirements the hunter may prevail upon his friends to enter the alien country on a raiding expedition, thus adjusting to the cooperative effects of his enemy's comrades in defense. At the same time, he may choose to make the raid in the early hours of the morning when he knows it is the custom for his enemies to be sleeping. Such responses are in adjustment to the additional requirements imposed upon his problem by the fact that the enemy, unlike the pig and the stone, is a member of another society.

It will be noted that certain requirements imposed upon the warrior's behavior depend upon the way in which the enemy reacts to the situation. When the enemy sees the warrier he will act as he has learned to act when he sees a person whose characteristics identify him as a warrior from a hostile tribe. The enemy will thus identify the stranger as a hostile warrior and this will be the cue to a specific set of learned responses. If the warrior could avoid being placed in this category, or delay such recognition, he might partially nullify the requirements imposed upon his responses by the reaction to him on the part of the enemy. This explains in good part the advantage of responses such as sneaking up quietly upon the enemy, using camouflage or disguise, and attacking when the light is so poor that it is difficult to see.

It has been pointed out that human behavior is learned according to the principles of learning. Learning principles always operate in a learning situation composed of certain conditions. The conditions composing such a situation are relevant to the learning process if they provide cues, influence drives, or limit possible responses. Moreover, learning only takes place in a dilemma, *i.e.*, when an organism is faced by a problem. Problems arise when the drive-specifications are not immediately met by the existing situation. The problem thus posed is one of changing the conditions of the situation so as to bring about a rewarding situation, *i.e.*, one which will fit the drive-specifications. In solving such problems, responses must conform to the laws governing changes in the condition-types involved if they are to be successful. Those responses which are consistently followed by successful changes in conditions are the ones which are learned and persist. Culture, therefore, is composed of responses which have been accepted because they have met with success; in brief, culture consists of learned problem-solutions.

# COSMIC EMOTION

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EVERY one of us is born into a wonderland—the universe in which we live and move and have our being, and which, from the dawn of human thinking, has exerted a profound fascination upon the mind.

Man's reaction to the riddle of the universe is an interesting study, leading to a conclusion perhaps rather unexpected—that in this respect modern man differs less from his primitive forbears than might be supposed. An analysis of the cosmic emotion evidenced in the earliest human records reveals six principal elements in its composition, five of which are to be found in modern man, all qualitatively unaltered, though in some cases much intensified. The sixth element, though strong in earlier times, has now almost faded away, but its place has been taken by a seventh element of distinctly modern origin.

First and foremost among these permanent elements we may place wonder and its invariable concomitant, curiosity. The presence of these elements in very young children testifies to their ancient racial character. It is recorded that the physicist Clerk Maxwell, in his early years, was continually asking his elders: "What is the go of that?" Every parent can match this from his own experience, and primitive man doubtless asked many such questions with no one to answer them. But curiosity, like hunger, becomes stronger the longer it remains unsatisfied, and lacking an answer it will manufacture one for itself.

The records of the past are full of such guesses at the causes of natural phenomena, mostly anthropomorphic in character. The stormy waves of the sea were caused by the wrathful strokes of Neptune's trident; the attraction of the magnet for iron was due to an indwelling spirit, and the thunderbolts of Jove still live in poetic parlance. Gradually, however, man learned that there was one source from which he could obtain an answer to his questions—nature herself. It has been well said that an experiment is a question put to nature, and it is interesting to reflect that the experimental method and the growth of modern science have their origin in the urge of these two primitive instincts—wonder and curiosity.

Primitive though they may be, these elements are still with us. Time has but strengthened and ripened them, and widened their field of application. It is no longer necessary that an occurrence be rare or spectacular to excite our wonder. We have learned that the simplest and most commonplace natural phenomenon, even the falling of an apple from a tree, is, when we stop to think about it, as Newton did, wonderful past all speaking. Nor is this recognition of the wonder of the commonplace confined to scientific men.

Seventy years ago, some of William Kingdon Clifford's most successful popular addresses on science were given before audiences of London working men. It is true that Clifford was the greatest master of lucid exposition in our language, but some of the credit must be given to the receptive audiences. It is unthinkable that even a Clifford could interest, say, a primitive group of Australian black-fellows in such subjects without the liberal use of experiments according to the classical definition—involving a bright light or a loud noise.

Several years ago I was asked to de-

liver an address before the scientific staff of the General Electric research laboratory at Schenectady, and also to make a popular broadcast from their radio station. As a subject for the address to the staff I suggested: "Old and new ideas about gravitation," and for the radio broadcast: "Practical suggestions for improving the acoustics of buildings." I was advised by the management of the radio station to use the same subject for the broadcast that I had chosen for the staff meeting, as their experience told them that it would excite the greater popular interest.

The third element in man's cosmic emotion is reverential awe. This also dates back to remote antiquity, as is evidenced by the world-wide prevalence of sun worship. With the passing centuries this element has lost none of its strength. It has been a favorite theme of the poets, ancient and modern. The words of the Psalmist are familiar to us all:

The heavens declare the glory of God, and the firmament showeth his handywork.
Day unto day uttereth speech, and night unto night showeth knowledge.

Three thousand years later Tennyson expresses the same feeling:

Flower in the crannied wall,
I pluck you out of the crannies:—
Hold you here, root and all, in my hand,
Little flower—but if I could understand
What you are, root and all, and all in all,
I should know what God and man is.

Closely connected with this element of reverential awe and, in fact, a corollary to it, is man's feeling of his own insignificance as compared with the physical universe. David gives expression to this also:

When I consider thy heavens, the work of thy fingers,
The moon and the stars which thou hast ordained,
What is man that thou art mindful of him?

With the growth of our knowledge of the universe this feeling of our own physical insignificance has been greatly intensified. It is perhaps not generally realized how small the ancients believed the universe to be. The Greeks placed the abode of the gods no farther away than the summit of Mount Olympus. Omar Khayyam complains of his cramped quarters:

And that inverted Bowl they call the Sky,
Whereunder crawling coop'd we live and die—

A legend of the days of Mohammed tells how the Prophet made a round trip to heaven and back in one night, mounted on a miraculous steed, to confer with Allah about the number of prayers to be required of the faithful. Even allowing for the element of the miraculous, such a legend could hardly have taken root and flourished in the environment of our modern ideas of the size of the universe. Contrast the ancient concept of the universe with that of the present day, and we can begin to appreciate how much this feeling of physical insignificance has been intensified.

But no matter how insignificant an individual may feel, there is a certain measure of compensation in feeling one's self to be a member of a large group, and the larger the better. For this reason speculation as to the possibility of intelligent life elsewhere in the universe has been particularly attractive to our earth-bound race.

A generation ago there was much discussion of the question of possible inhabitants of the planet Mars. Little is now heard of this in scientific circles. Cosmically speaking, life as we know it is a delicate hot-house plant, capable of existing only within rather narrow limits of temperature and composition of atmosphere, and every increase in our knowledge of these conditions as they prevail on Mars has made the existence of intelligent life on that planet more and more improbable. The same applies to all the other planets of our solar system; they are either too hot or too cold, or their atmospheres lack sufficient oxygen and water.

But are not the stars of heaven suns

like our own, and among these millions of suns and their attendant planets is it not reasonable to suppose that there may be a few thousand bodies as well fitted as our earth to sustain human life?

For this question astronomy has rather a staggering answer. It is true that these stars are suns, but it does not necessarily follow that they all have planetary systems. It fact, it is now regarded as quite possible that but very few of them are so favored. Jeans goes so far as to call our system a freak system, and to suggest that there may be but one other like it.

There is to-day no perfectly satisfactory and generally accepted theory of the origin of our solar system. That the planets once formed part of the sun is beyond doubt, but how they came to be detached from it is still uncertain. Laplace's nebular hypothesis, after a reign of more than a century, had to be abandoned, as it was found that it failed to satisfy an important condition of celestial mechanics. Several other hypotheses have been proposed, none of which is completely satisfactory, but all of which agree in ascribing the origin of the solar system to a close approach or a grazing collision between our sun and another star. And so widely scattered are the stars of heaven that such an encounter could not be expected to occur oftener than once in ten million million years. Our little colony of life may be only an ant hill in a vast desert, and man's feeling of physical insignificance is intensified by a sense of cosmic loneliness.

These four elements—wonder, curiosity, reverential awe and physical insignificance, have been features of man's cosmic emotion since earliest times, and bid fair to remain so as long as our race shall last. Such changes as time has wrought in them have been quantitative, in most cases an increase in intensity. To these four is to be added a fifth, which, though prominent in bygone years, has now almost faded away—superstitious fear.

During the Middle Ages it was the universal custom in Europe to ring the church bells on the approach of a thunderstorm with the idea of frightening away the Prince of the Power of the Air and his attendant demons. Bells are still to be seen in old churches bearing inscriptions such as "I break the lightning," or "I put demons to flight." In earlier days this fear often prompted human sacrifice in times of famine or pestilence, to appease the supposed anger of the gods. In some places, on the principle that prevention is better than cure, a human victim was sacrificed annually in the spring of the year in order to ensure fertility of the fields during the coming season. In our time this element of superstitious fear has all but disappeared, but its place has been taken by another element, qualitatively new, and of distinctly modern origin.

The supposed agency of demons and spirits in natural phenomena has, with the modern development of the sciences, been replaced by physical causation and laws of nature. These laws are now so well understood that we can, for instance, predict with reasonable accuracy a clear or rainy morrow, and with perfect accuracy an eclipse of the sun. Passing from the macrocosm to the microcosm, we have learned the cause of many diseases and the cure for some of them. We prefer lightning rods to church bells and antitoxins to incantations. Though much of nature is still beyond our prediction or control, it is no mean attainment to have achieved a sufficient intellectual mastery of our environment to begin to understand it. And as we pass the Cosmos in review before the mind and reflect that of all nature man alone has achieved this mastery, there wells up within us a sense of intellectual superiority that goes far toward alleviating our feeling of physical insignificance. Man may be but the merest speck in the universe, yet in his intelligent comprehension of it is he not but little lower than the angels?

In the year 1875 the physicist Maxwell gave this growing feeling of intellectual superiority a powerful stimulus.

The more we have learned of the laws of nature the more profound is the respect which they have inspired. Like the laws of the Medes and Persians, they alter not. We may defy them, but no one is sufficiently influential to escape the consequences of his defiance. Such progress as we have made in the control and utilization of natural forces has been attained by making allies of some of them, and cunningly pitting one force against another, as, for instance, the air resistance to a parachute against the force of gravity on the aviator. Imagine then the effect produced in the scientific world when Maxwell pointed out that it lies within the power of intelligence to reverse the action of one of nature's fundamental laws, known as the second law of thermodynamics.

According to this law heat, like water, when left to itself, naturally runs down hill. If we put a cold spoon in a cup of hot tea the spoon becomes warmer and the liquid cooler. This transfer of heat from the higher level of temperature to the lower will continue until both spoon and liquid reach a common level of temperature. It would be against all experience to expect the spoon to become colder and the tea hotter.

It is true that water can be raised from a lower to a higher level, but only by expending work upon it, as, for instance, by lifting it in a bucket or by working a pump handle. And it is possible to make heat run up hill from a cool body to one that is warmer, but, as with water, only at the price of expenditure of work. But Maxwell showed that it is theoretically possible for intelligence to bring this about without expending any work. The practical difficulty is that we lack for the present a vision keen enough and a touch delicate enough to see and handle the single molecules of which all bodies are composed.

Of the three states of matter, solid, liquid and gaseous, the structure of a gas is the simplest, and it was upon this that Maxwell based his demonstration. Imagine a swarm of bees flying about in a closed box, colliding with each other occasionally, and rebounding from the walls of the box. Suppose also that some of the bees are flying rapidly and some slowly, while the majority are flying at intermediate speeds, and you will have a good idea of the structure of a gas. The molecules of which a gas is composed are, of course, very small, far too small to be seen with a microscope, but their number is so great and their velocities so high (of the order of a mile a second) that the pressure produced by the joint impact of millions of these molecules upon the walls of the containing vessel is by no means inconsiderable. This it is, in fact, which sometimes bursts a steam boiler.

When we say that a gas or a vapor is "hot" it is our way of expressing the physical fact that its molecules have a higher average velocity than those of a cooler gas. The molecules of the hot steam inside the boiler are moving much more rapidly than those of the air outside, and the pressure on the boiler plates from within is greater than the counter pressure from without. The wall of the boiler is supposed to be strong enough to take care of this difference of pressure, but if the water is kept boiling vigorously the number of steam molecules continually increases until their joint impact is so great that the boiler plates give way.

Returning to Maxwell's argument, imagine a gas contained in a vessel divided into two parts by a partition, and suppose the gas on either side of the partition is at the same temperature, that is, the molecules on each side have the same average velocity. Suppose that there is a tiny door in the partition, in charge of a little intelligent being who can see the molecules and distinguish between the

rapidly moving and the slow ones. When this being sees a rapid molecule in the right hand compartment headed for the door it is his duty to open the door, and let the molecule pass into the left compartment, but he is to keep the door closed against slow molecules on the right. Conversely, he is to allow only the slow molecules to pass from left to right. By this sorting process the average velocity of the molecules on the right will continually decrease, while that of those on the left will increase. The effect of this will be that the temperature of the gas on the left will rise while that of the right will fall, and heat will run up hill.

This argument of Maxwell's is something more than an interesting fairy tale. It teaches us that when, from our experience, we have formulated what we call a law of nature we are not to regard this as the last word on the subject; that nature's way of working when left to herself may be radically altered when intelligence takes the reins. Nor is the necessary degree of intelligence to be regarded as an unattainable ideal. Much progress has been made in this direction since Maxwell's day, and more will be made in the future. While we are not yet able to see molecules we can do many things with them without seeing them. We can, for instance, count the number of molecules in a cubic foot of a gas with at least as great accuracy as we can count the population of New York City.

There is much justification for the feeling of intellectual superiority with which man surveys his environment. The intensity which this feeling may attain is well illustrated by an old story.

It is said that at one time an astronomer discovered a new star, which he found by his measurements to be approaching the earth with a high velocity. He calculated that it would strike the earth in a few months. He did not announce his discovery, fearing to witness the orgy of lawlessness and despair which might follow such an announcement, but night after night he studied this approaching doom, fascinated by it. One night he spoke out and addressed the star as follows:

"I know that you will soon destroy me and everything living, but I can calculate the day—nay, even the hour when this will happen, while you are but a blind, brute thing, and I would not change places with you!"

There is one more element in our cosmic emotion to be considered. Man finds himself in a wonderland which excites curiosity and inspires awe. He feels his own physical insignificance and the transitory nature of his stay, and yet he is not content to be a mere "super" in the cosmic drama, but feels qualified for a speaking part. He wants to be remembered, he feels an urge to leave his mark on the universe, at least upon such portion of it as is within his reach.

We can trace this element far back into antiquity. This it was which built the pyramids, and which prompted the proud boast of the Roman emperor who said: "I found Rome of brick, and left it of marble." In modern times this element has suffered a qualitative change, and has assumed a form less materialistic and more altruistic, but the primitive urge is still there. When the founder of the Smithsonian Institution made his will by which his estate was left to the United States of America, "for the increase and diffusion of knowledge among men," his solicitor expressed surprise at this unusual bequest. Smithson replied: "My name will be known among men when the Percys and Northumberlands are forgotten."

But after all, such monuments, physical or intellectual, can affect only a tiny fraction of the universe—our earth and its inhabitants. In ancient times, when the earth was regarded as the most important part of the visible universe, one might reasonably feel that in beautifying a city or in bettering human society he

had done something of cosmic importance, but with our broader outlook the case is different. Not that this detracts in the slightest from the laudable character of such efforts, but considering our cosmic insignificance all such efforts must be recognized to be of but local and temporary importance.

But there are times when all of us find it a relief to think qualitatively rather than quantitatively. Archimedes, that pioneer mechanical engineer, is reputed to have said: "Give me a place where I may stand, and I will move the earth." The modern engineer does not even ask for a place to stand, for he knows that by merely shooting a bullet in an easterly direction he can (to a microscopic extent) play the part of Joshua and lengthen the day. Moreover, he knows that (still qualitatively speaking) he can perform actions whose results reach far beyond terrestrial limits. When he strikes a match to light his cigarette as he walks down the street, he knows that he has started light waves, some of which will travel outward and onward in space, perhaps forever.

With increasing knowledge of the universe our eyes have been opened, and we see that our actions may sometimes have a small measure of cosmic scope. It is inevitable that this should lead to speculation as to the possibility of broadening and increasing our cosmic reach. But here we leave the realm of fact and enter that of fancy. It is an attractive realm, as we all know, and by your leave I will tell you another story.

As I journeyed through the world I came to the shore of an ocean reaching far as the eye could see. The water of this ocean was colorless and transparent, and was ceaselessly in motion; even in parts where there were no breakers the water was continually moving in currents. And as I walked along the shore I noticed that there was no living thing in the water, not even a blade of seagrass; nor did any living thing appear on the beach as far as I could see inland. Thus I wandered ever along the shore of the ocean, watching for some living thing, but finding none.

At length, after many miles of traveling, I came to a place where the sea ran inland, forming a little pool wherein the ceaseless currents played. By the side of this pool there lay an old man, gazing intently into the beautiful clear sea water, and my heart was glad at the sight of a living thing.

"Tell me, father," said I, "what is the name of this ocean? And what curse is laid upon it that there is no living thing in its waters?"

The old man looked at me for some moments without speaking. Then he said, apparently ignoring my first question:

"There are living things in it, but they are few."

"I have traveled many days," said I, "but I have seen none."

"When I was your age, my son," said the old man, "I traveled many months before I found them, and I have lain here watching them ever since."

I looked in the pool, and I saw amid the ceaseless water-currents a swarm of living things, hollow, clear-walled creatures, some like single bubbles, some like a heap of bubbles fused together; and the sea water within them was colored a beautiful rich tint which was new to me. I saw that in those creatures which were composed of many bubbles the color was deep, while in the simpler ones the color was paler, and in the single bubbles I could detect no color at all. I watched the creatures swimming about and pulsating rhythmically, and I said to the old man:

"They are beautiful! And are these the only living creatures in the ocean?"

He shook his head. "I do not know. The ocean is so vast—there may be others—but I have found none."

I looked again in the pool, and I saw that some of the creatures lay still, and

their color was paler than that of their fellows of like degree of complexity. The old man said: "They are sleeping." And I saw one creature which, from its complexity, should have had the deepest color of all, but it lay motionless and colorless; and the old man said: "It is dead."

I asked the old man: "What gives to the water within the living creatures its color? Do they secrete coloring matter?"

He answered: "I thought so when I first began to study them, but it is not so. Do you see the hairs that line their internal cavities?"

I looked, and I saw that the creatures had little hairs within, and that these hairs were constantly moving, beating and churning up the sea water within. The old man said: "When the sea water is beaten thus it suffers a subtle change and becomes colored."

And I said: "Why then is not the whole ocean colored, since it is ceaselessly beating upon its shore?"

The old man said: "I do not understand it; but it seems that it becomes colored only when it is stirred up by living creatures."

As I silently mused over this my ear caught the sound of a faint chirping. The old man said: "It is made by the creatures in the pool. The more complex ones are able to utter sounds, and the highest of all are even able to communicate with each other by this means."

"They talk!" said I. "Then they must think!"

"Ay, that they do," said the old man, "and strange and sad are some of their thoughts; for in the years that I have studied them I have come to understand a little of their language. For instance, this beautiful color is to them the very essence of the pleasure of their lives. The deeper colored pity the paler, and pity most of all those single bubbles which appear devoid of color."

"Are they really colorless?" said I, "or is their color only so pale as to be imperceptible?"

The old man bade me look again in the pool.

"Do you see," said he, "how the most complex and active creatures, having many hairs moving, are the deepest in color, and how those with fewer hairs to churn the water are paler? Are the single bubbles totally devoid of hairs?"

"No," said I, "they have a few, and these move slowly."

"What think you then? Are these devoid of color, or is it simply a question of degree?"

I felt that my question was answered.

"Ay," continued the old man, "it is a question of degree; for once or twice in the years that I have watched them I have seen single bubbles, under stress of great excitement, churn the water within them so vigorously with their few hairs that it assumed a pale tint."

Then I said, remembering how I had seen the sleeping ones and the dead one: "The depth of color in any creature seems to be proportional to its bodily activity; and among different creatures, to their complexity."

"Right," said the old man, "and this fact has been recognized by the most complex creatures themselves."

I said: "When the creatures sleep or die, and their color fades, what becomes of it? Is the change produced by beating the sea water so unstable that when the beating ceases the water reverts to its colorless condition?"

The old man looked grave. "So I thought at first, and many a sad hour have I passed thinking of the labor spent in producing this beautiful color, so unstable that it was doomed to perish with the ceasing of the labor that produced it. But," and here his face brightened, and he spoke with assurance, "it is not so. This change once produced is permanent; it can never be undone."

"But what then becomes of the color?"

He pointed to the pool, and I looked in. One of the most deeply colored creatures was just falling asleep. Slowly and still more slowly moved the hairs within it, and its color gradually faded. I watched closely, but I could not see where the color went. Then there came an instant when the ceaseless wash of the currents slackened, and in that instant I saw the water about the creature tinged with the beautiful color. I looked up at the old man.

"Ay," said he, "the color is permanent; but the colored water continually diffuses through the creature's body, waking or sleeping, and is dispersed and diluted in the vast ocean. When they sleep their motion is so far reduced that diffusion renders them pale; and when they die they become absolutely colorless. But the color does not die, the beautiful color—no, it can not."

"And do they know this?" said I, pointing to the pool. His face again became grave.

"I find that there is a great difference of opinion among the most complex of them. They all realize that it is this color that makes their lives worth living, and they recognize that its intensity is proportional to their bodily activity. They have an instinctive feeling that the color is permanent, but they are sorely puzzled to account for its fading during sleep and its disappearance at death; so that some say that this instinctive feeling of the permanence of the color is a delusion; that the color is really a most unstable thing, and that colored sea water can exist only within a living organism. This conclusion they sorrowfully accept and make the best of it. Others there are who refuse to accept it, and who cling to their instinct." And the old man sighed as he looked at the restless wash of the water in the pool. Presently he said:

"How long will it take, think you, until the whole ocean becomes of this beautiful color?"

I said: "If there be other creatures elsewhere, and many colonies of them—"

"Nay," said he, "I know not if there be such—I hope—but how long?"

I looked long and silently in the pool. Then I said:

"I see some creatures that are very pale; and they are not asleep, for they are moving about."

The old man's brow grew dark. "These are lazy ones," said he. "They have allowed themselves to become discouraged, and say: 'Why should we labor and beat our hairs to produce a color which must perish with us?' These are they that retard by just so much the coloring of the ocean."

"Nay, father," said I, "be not angry with them. It is but natural. Remember that they do not know."

"True," said he, and his face grew kind and pitiful. "They do not know."

Said I: "Suppose some great falling rock should crush these creatures out of existence?"

"But the color!" said the old man. "The color can not be crushed out of existence! And the ocean is so vast—there may be other colonies elsewhere; and even if there be none now, they may in time arise as this colony has done, I know not how. The ocean will be colored!"

I was silent a long time. Then I happened to think of my first question, which still remained unanswered.

"Tell me, father," said I, "what is the name of this ocean?"

"I have never heard but one name for it," said he, "and that is the name given it by these creatures themselves. 'Tis a strange name; there is no exact equivalent for it in our language. The nearest is Energy-of-the-Universe."

"And what do they call this beautiful color?"

"They are not agreed upon a single name. Some call it Consciousness, and some call it Soul."

# BOOKS ON SCIENCE FOR LAYMEN

## THE UNIVERSITY AND THE FUTURE OF AMERICA[1]

A SIGNIFICANT program was arranged to celebrate the fiftieth anniversary of the founding of Stanford University. Sixteen of America's busiest scholars who have contributed largely to the world's thinking accepted places on that program. Manuscripts of the addresses were assembled and edited by President Ray Lyman Wilbur under the above title. The theme selected for the celebration had been given to each speaker. Each one selected a theme for himself, which appears as his own chapter heading, but presumably each kept in mind the main theme of the entire program. However, that main theme was often quite eclipsed by the speaker's forceful and appropriate presentation of his own guiding stars which have led him in his preceding decades of work. That was inevitable, since thoughtful men usually are best when speaking of matters to which they have given prolonged and fundamental consideration. Even so, sixteen addresses, each masterful and distinct, may provide good foundation for study of the problems of "The University and the Future of America." Few of the speakers ventured into prophecy, mostly leaving what they said as sorts of known scaffolding extending off from the shore a little way, but not leaving the footing of secure land for less stable and turbulent areas of the open sea. The impossibility of writing a true review of this book does not constitute an adverse criticism. Had the book merely been scanned for general impressions, the preparation of this account would be less difficult.

In the first chapter, the reader follows President Isaiah Bowman in his almost poetic analysis of what people want, why and how they achieve it, his comment that usually people think "heaven is the absence of extreme heat or extreme cold; to others it is the absence of hunger, or sorrow, or night bombing." But to Bowman "heaven . . . is a state of social mind that tries to do something about the future, and looks around for means to ameliorate unnecessary hardship and to foretell a wise course of community action. . . . Science is manageable and swift in development largely because it is impersonal; atoms do not care. Social objectives . . . are the expression of a people's will, . . . when each man is thinking of his own good and only a few are thinking of the general good." But since it is the scientist who knows the atoms which "do not care," and since the scientist is surely a part of the social problem, he can not rightfully continue to escape his participation in its solving. Intelligent and educated people must all accept their personal part in society's problems. To laugh these off is stupid and suicidal. Bowman devotes much of his chapter to showing how his foundational conceptions might affect problems of conservation of natural, human and cultural resources. "We make a fundamental mistake if we suppose that we have either conquered nature or come to the end of our knowledge about her." But we must act every day though we often possess only part of the needed knowledge. Even democratic choices are often very unintelligent and badly willed. Eight guiding principles are developed and urged for adoption and use. These recognize the past, use the present and anticipate the future. Indeed one could with justice "define civilization today as an operating system of statistical services whose progenitors are found in the old Babylonian Kingdom. . . . statistics about the tools are almost as important as the tools." And the

[1] *The University and the Future of America.* Ray Lyman Wilbur and fifteen others. ix + 274 pp. $3.00. 1941. Stanford University Press.

future "is not all mystery. . . . the outcome is dependent upon our own intelligence, endurance, imagination, and will."

Professor E. O. Lawrence's chapter on "The New Frontiers in the Atom" is a cogent summary of atomic research as applied to the periphery of its area of present knowledge. To review the chapter would be to repeat much of it. Robert A. Millikan, great teacher that he is, turned his attention primarily to three fundamental needs in American education; selection of those who are competent to be educated in our present system, and rejection of the large numbers not competent; development of types of schools, shops and apprentice situations in which there may be trained the large numbers not competent to benefit by the present educational system; and citizenship education to the end that "at least fifty-one per cent. of the voters are capable of casting intelligent votes, and this requires a fairly broad education up to the age of seventeen or eighteen."

Roscoe Pound's chapter on "Education and Social Control through Law" justifies publishing the book. That certainly is true also of Edward Lee Thorndike's "Human Resources." Indeed, these two preeminent scholars have produced chapters which might well be required reading in their respective fields for every one who wants foundations for guidance regarding the objectives and means of human advance as well as clear limits on what is now known.

Education for Women (Aurelia Henry Reinhardt); Biological Basis of Human Nature (Herbert Spencer Jennings); Unified Approach to Knowledge and Life (Lewis Mumford); Science as a Liberal Education (Edwin P. Hubble); Medical Investigations (Walter B. Cannon); New Products (Charles F. Kettering); American Writers and the Future (Archibald MacLeish); The University and the Changing Society of the Future (William F. Ogburn); Economics, History, and the American University of the Future (Edwin F. Gay); and Résumé, by Herbert Hoover, complete the list.

OTIS W. CALDWELL

## THE CHEMICAL CONTROL OF BACTERIA[1]

THIS is an ambitious little book designed to answer the most penetrating curiosity about the whole science of control of bacterial infection.

The first two chapters do an amazingly complete job of presenting in a nutshell both the theory and the practical aspects of infection and immunity. This is done with sufficient clarity to afford satisfying refresher material for physicians and others having some scientific background, yet so simply as to build a tangible picture for even the lay person.

The qualifying title of the book, "From Salvarsan to Sulphapyridine," justifies devotion of all beyond the first two chapters to chemotherapy. The early history of the development of drugs leads fascinatingly to the birth of organic chemical industry and the opening avenue to synthetic chemicals in medicine. Domagk's discovery of Prontosil introduces the remarkable new class of sulpha-drugs, the story of which is the real excuse for publication of this little volume.

In every step in his account, the author attempts to lay the scientific groundwork for a fairly sound background for the person who has had no training in science. This spadework for his presentation of synthetic organic chemistry is in some ways almost too detailed to be needed by any one with even high-school chemistry experience, yet in certain specific respects is too involved to mean much to any but those whose training already fits them for appreciating an unsimplified direct approach to chemo-

[1] *The Conquest of Bacteria.* F. Sherwood Taylor. Illustrated. 177 pp. $2.00. March, 1942. The Philosophical Library.

therapy. It would be only for these, for instance, that the justification of picturing atoms as hard spheres would be comprehensible. And the value in giving so much space to graphic organic formulae is easily open to question. To the person who is already familiar enough with chemistry, the author had undoubtedly made clear what is meant by "related drugs," hence what guide there is in the search for therapeutic chemicals. He has shown the difference between modifications which alter therapeutic properties and those which simply get around patent restrictions. He has given some notion of what is meant by "the peculiar atom pattern of quinine" which resists synthesis. He has emphasized the complex nature of all these compounds, therefore requiring expensive synthetic processes, trained chemists and the need for funds.

Not only is the last chapter devoted to a plea for public support of research, which Professor Sigerist commends in his foreword, but this point is made repeatedly in connection with each drug discussed.

The table of sulphonamide derivatives, with commercial names, is certainly revealing to the lay person and should be especially appreciated even by the average physician.

Some incidental features of the book deserve special commendation: The description of what it means to assay drugs will interest everybody. The reasons for not practicing self-medication are wisely included in a book for public instruction. The constant use of mortality statistics in illustrating the effectiveness of biological products and of drugs. The discussion of control of clinical tests and the paragraph on estimation of experimental validity are excellent. The discussion of "scientific method" of approach which high-school science teachers will appreciate for instructional purposes, and which will surely make "scientific thinking" more meaningful to the everyday readers.

There are many typographical errors that should be corrected before the next printing, but this comment on the careless proofreading is not intended to reflect on the general excellence of content.

J. BRONFENBRENNER

## ADVENTURES IN CALIFORNIA SCENERY[1]

AMERICAN geologists have not been particularly successful in popularizing American geology; in fact, not many professional American geologists have attempted to make geology interesting to laymen. I. C. Russell's books on the rivers, lakes, glaciers and volcanoes of North America are shining exceptions, but they were published during the period from 1895–98 in a now outmoded format.

Mr. Willard's well-illustrated book is a popular account of California geology, part of which is written as an automobile guidebook. To geologists California geology is exciting, particularly on account of the crowded succession of events during late geologic time. It is not an easy task, however, to translate the events into a history appealing to laymen. Reed's "Geology of California" (1933), which is not included in the bibliography, and Reed and Hollister's "Structural Evolution of Southern California" (1936) summarize the work of California oil geologists, the results of which have revolutionized California geology during the last two decades. Both of these professional books might have been used to greater advantage in the preparation of "Adventures in Scenery." Reed's imaginative genius imparted to his accounts of geologic history an epic quality that would attract laymen.

W. P. WOODRING

[1] *Adventures in Scenery;* A Popular Reader of California Geology. Daniel E. Willard. Illustrated. x + 438 pp. $3.75. 1942. Jaques Cattell Press.

## A LAYMAN'S HISTORY OF THE THEORY OF RELATIVITY[1]

THE author of this excellent little book sets for himself a double aim: to describe the historical development of scientific thought which prepared the ground for the formulation of the theory of relativity, and to analyze on this basis the fundamental physical principles and philosophical concepts of this theory.

The opening chapters of the book enroll before the reader's eyes the picture of the young physical science struggling through the difficult period of medieval history, and show how hard it was at that time to conceive and to spread about the ideas which look so natural and elementary to us to-day. The discussion shifts then to the more recent era, when the questions concerning the existence and the possible physical properties of the so-called world either came into prominence. This leads naturally to the famous experiment of Michelson which turned out to be a tombstone to all the mechanical views concerning the nature of light, and whose unexpected result represented at its time a real challenge to the scientific mind. The author relates farther how this challenge was taken up by Einstein, and how the attempt to interpret correctly this seemingly isolated physical experiment led to a deeply felt revolution in the entire field of physical science, causing scientists to change in a very fundamental way their customary views concerning space, time and motion. The chapters devoted to the more detailed discussion of the special and general theory of relativity are written in a very simple and easily understood way, and would give to a layman, only vaguely familiar with the facts and laws of modern physics, a very clear picture of "what it is all about."

This book can be readily recommended to everybody who wants to know what "the theory of relativity" is.

G. GAMOW

[1] *From Copernicus to Einstein.* Hans Reichenbach. 123 pp. $2.00. 1942. Philosophical Library.

## A YEAR BOOK OF PUBLIC HEALTH[1]

A RETIRING professor recently told me that his life had been a very happy one because he had new students each year learning from him things that were old to him but new to them, and that he himself had always new things to learn. Some of those trained in public health need to be reminded each year of the new things they must know, as well as the general field of public health, through which they must guide many others.

The 1941 Year Book of Public Health is a practical handbook that ranges from rape to Rocky Mountain fever and from encephalitis to fluorine. Dr. Geiger as editor has used his long experience as a health officer and teacher in making choices of the subjects to be dealt with and how much space each should be given. Air-raid casualties, evacuation ports, bombed water mains are certainly timely topics for doctors, public health workers, nurses and those citizens engaged in civilian defense work of all sorts.

The world-wide spread of diseases, especially from the tropical or subtropical areas, gets much less space than it will in the edition for 1942. Yellow fever and yaws get a hearing in the present edition suggestive of what will come in the years immediately ahead.

The book is a good and useful compendium that should find wide use in this time of direct concern of the whole public in health problems.

RAY LYMAN WILBUR

[1] *The 1941 Year Book of Public Health.* J. C. Geiger, editor. Illustrated. 544 pp. $3.00. 1941. Year Book Publishers.

ROSS AIKEN GORTNER

# THE PROGRESS OF SCIENCE

## ROSS AIKEN GORTNER, 1885–1942

THE lamented death of Dr. Ross Aiken Gortner on September 30, at his home in St. Paul, Minnesota, removed from the ranks of American agricultural and biological chemists one of their most distinguished leaders. Gortner's work as investigator, teacher and author was so many-sided that there are few branches of applied biochemistry in which his influence is not felt.

Gortner was born at O'Neill, Nebraska, on March 20, 1885, and at the age of 17 entered the preparatory school of the Nebraska Wesleyan University at Lincoln, where he obtained his first instruction in elementary chemistry. Both here and in the associated university he made a brilliant record in chemistry under Professor F. J. Alway, who appointed him laboratory assistant and exerted a friendly influence on his career, not only then but later, in many ways. Evidences of this association are a number of joint publications on nitroso compounds, detection of bleached flour and studies on soils. After obtaining his B.S. degree at Nebraska Wesleyan in 1907, Gortner, on Professor Alway's advice, took a course in physical chemistry at the University of Toronto, where he earned his M.A. degree in 1908 under the late Professor W. Lash Miller for a thesis on "The Induction of Ferrous Salts of the Reaction between Chromic and Hydriodic Acids." For the completion of his academic training Gortner went next to Columbia University, where he obtained his Ph.D. degree in 1909 under Professor Marston T. Bogert, for an investigation in organic chemistry "On Some New Quinazoline Derivatives."

The years 1909–1914 were spent by Gortner as resident investigator in biochemistry at the Carnegie Station for Experimental Evolution at Cold Spring Harbor. It was during this formative period, when the foundations of his future scientific career were being laid, that Gortner's interest in biochemistry was aroused through a lasting friendship which he formed with the late Dr. J. Arthur Harris. In a beautiful tribute to this eminent botanist Gortner wrote in 1936:

> For more than twenty years I tried to absorb what I could of his philosophy of life and, sitting at the feet of a master, sought to learn from him how to integrate the random elements of natural science into a complete picture of the biological reactions of the living organism.

One result of this association with Harris was the collaboration by the two friends in an extensive research on the physico-chemical properties of vegetable saps, the results of which were published in some twenty papers.

In 1913 Dr. A. F. Woods, dean of the College of Agriculture of the University of Minnesota, invited Dr. F. J. Alway to join his faculty as professor of soil chemistry, and in 1914 Gortner was persuaded to become a member of his staff as associate professor of the same subject. This renewal of associations with his former teacher was a source of great satisfaction to Gortner as it afforded him a most favorable opportunity both for research and for realizing his cherished ambition of becoming a teacher of science. In 1916 he was made associate professor of agricultural biochemistry. His promotion to professor and to chief of the Division of Agricultural Biochemistry at the Minnesota Agricultural Experiment Station followed in 1917—a double field of activity which Gortner filled with distinction for the next twenty-five years.

Gortner's first biochemical researches, performed at Cold Spring Harbor, re-

lated principally to animal pigments, the chemistry of embryonic growth and the joint work with J. A. Harris on vegetable saps. His numerous investigations, conducted either singly or with students, at Minnesota comprised such topics as the organic matter of soils, the acid hydrolysis of proteins, sulfur in proteins, the state of water in colloidal and living systems, and applications of colloid chemistry in the study of flour and bread and in the investigation of plant and animal substances. In 1929 Gortner published his "Outlines of Biochemistry," of which a second edition appeared in 1938. This work met with a wide reception; eight well-worn copies in the library of the U. S. Department of Agriculture bear witness of its popularity and constant use among agricultural chemists.

The scientific recognition won by Gortner at Minnesota led to numerous requests for his services as lecturer at other institutions. He was the Wisconsin Alumni Foundation lecturer in 1930; the Priestley lecturer at Pennsylvania State College in 1934; and the George Fisher Baker lecturer at Cornell in 1935–36. His lectures at Cornell were published in 1937 under the title "Selected Topics in Colloid Chemistry." In 1936 Gortner with other colleagues at Minnesota prepared a memorial volume entitled "J. Arthur Harris—Botanist and Biometrician." It was through Gortner's influence that Harris in 1924 joined the faculty of the University of Minnesota where he was head of the Department of Botany until his death in 1930.

Although a biochemist of the first rank Gortner was never a narrow specialist and in his work as teacher, lecturer and writer the general relationships of biochemistry and other fields of endeavor were constantly stressed. His breadth of outlook is well illustrated in his address before the Pan-Pacific Food Conservation Congress at Honolulu in July, 1924, on "Agricultural Biochemistry and the Food Problem"; in his paper on "Biochemistry and the Problems of Organic Evolution," published in THE SCIENTIFIC MONTHLY for 1930; and in his article on "Biochemistry and the World Today" published in the *Sigma Xi Quarterly* for 1932. Gortner's range of scientific interests is also indicated by the numerous societies of which he was a member. He was a fellow of the American Association for the Advancement of Science; a member of the American Chemical Society (in which he held numerous offices as councilor, chairman of the biochemical and colloid divisions, associate editor, etc.), the American Society of Biological Chemists, the American Society of Naturalists (of which he was president in 1932), and the Society of Experimental Biology and Medicine. He was also a most active member of several honorary scientific societies, such as the chemical fraternity of Phi Lambda Upsilon (of which he was national president in 1921–26) and the Society of the Sigma Xi (of which he was national president at the time of his death).

In the devotion of time to advisory and committee work for the organizations of which he was a member, Gortner was always most generous. He was a member of the Willard Gibbs medal award and the Borden medal award juries of the American Chemical Society and as a member of the National Research Council was serving at his death on its committees for chemical and biochemical nomenclature, chemistry of proteins and colloid science. For his work in science Gortner was also the recipient of several honors. The honorary Sc.D. degree was conferred upon him by Lawrence College in 1932; he was elected a member of the National Academy of Sciences in 1935 and in May of the present

year he was awarded the Osborne Medal by the American Association of Cereal Chemists.

At the time of his death Dr. Gortner was engaged with his colleague Professor F. J. Alway on a comprehensive study of "The Sulfur Metabolism of Plants" under a grant awarded by a committee of the American Chemical Society in 1939 from the Herman Frasch Foundation for Chemical Research. Under the collaboration of the divisions of agricultural biochemistry and of soils at the Minnesota Agricultural Experiment Station considerable progress had been made upon this project which concerns the effect of sulfur-deficient soils on the growth and chemical composition of the crops grown thereon. Not only Gortner's associates but the entire world of agricultural science lament the irreparable loss which this and other incompleted investigations will suffer as a result of his untimely passing.

Colleagues and students all speak of the contagious love for science which Gortner imparted to every one with whom he came in contact whether in lecture room, laboratory or field. He radiated enthusiasm and his life was singularly rich in friendships, service and accomplishments.

The transmission of scientific influences from great teachers to their pupils was a subject that greatly interested Gortner in his later years. It was made the theme of his lecture on "Scientific Genealogy." The opinion of his friend Harris "that the teacher who lives in the lives of his students, and in their students in succeeding generations, provides a certain scientific immortality" finds its full expression in the life of Ross Aiken Gortner, for his memory is perpetuated not only in his published writings but in the work and careers of his many graduates.

CHARLES ALBERT BROWNE

## THE NEW YORK MEETING OF THE ASSOCIATION

IN view of the fact that travel by railway and bus must now be reduced to a minimum, it is fortunate that the annual meeting of the American Association for the Advancement of Science is scheduled for New York City from December 28 to January 2, because about three thousand members of the association live in New York City and its immediate suburbs, and about ten thousand within three or four hours' ride by train.

New York City is a favorable place for holding scientific meetings because of its excellent educational and cultural institutions and the many colleges and universities that are near it. Within greater New York itself there are Columbia University, New York University, Hunter

*American Museum of Natural History*

SOUTH FAÇADE OF THE AMERICAN MUSEUM OF NATURAL HISTORY

THE MEETING PLACE OF THE SECTION ON GEOLOGY AND GEOGRAPHY AND THE SECTION ON ASTRONOMY.

College, the Rockefeller Institute for Medical Research, the great medical centers of Columbia and Cornell Universities, the New York Zoological Park, the New York Botanical Garden, the Brooklyn Botanical Garden, the American Museum of Natural History and a dozen other institutions of distinction. And not far distant are Cornell University, Princeton University, Rutgers University, Yale University, as well as several well-known colleges and many high-grade secondary schools. In addition to these centers of interest in science, there are several hundred industrial research laboratories in New York and its near vicinity, such as the Bell Telephone Laboratories and the laboratories of the Barrett Division of the Allied Chemical and Dye Corporation, the Fleischmann Company, Merck and Company, the Standard Oil Development Company, the Atlantic Coast Fisheries Company and the Hercules Powder Company. Nearly all the directors of these laboratories and a large percentage of their technical staffs are fellows or members of the association. Finally, there are thousands of men and women in the New York area who are greatly interested in the progress of science even though they are not professional scientists themselves. Many of these persons will desire to attend the general sessions at which distinguished scientists will deliver addresses, and some of them will be interested in the technical sessions of the various sections and of the more than thirty affiliated societies that will meet with the association.

In addition to the foregoing positive

PARK AVENUE ENTRANCE OF HUNTER COLLEGE, NEW YORK
HEADQUARTERS FOR THE BIOLOGICAL SCIENCES AT THE CHRISTMAS MEETINGS.

reasons why New York is a favorable place for holding a meeting of the association at the present time, there is a negative reason. It would be impossible now to hold a great convention in Washington or Pittsburgh or Detroit because of congestion due to the war. In New York, however, there are few great war industries, such as those that are seriously interfering with the normal life of other cities. It is confidently expected that adequate hotel accommodations will be readily available at reasonable rates for all who will attend the meeting.

But what about the meeting itself? Naturally many of its programs will be strongly colored by the war that now involves almost the whole world. Perhaps the most far-reaching of these programs is the symposium on "Science Teaching in War Time," a subject that derives its very great importance from the fact that sixty-three per cent. of the men now being inducted into the armed forces of the United States will be used in technical branches of the service requiring scientific preparation far beyond that which most of them have had. Since plans are under way for an army of over seven million men, the problem of giving them the necessary basic scientific training is far beyond the physical and personnel capacity of the Army. Hence the schools, from secondary schools to universities, must be called upon. It is because of the urgency of this work that Brigadier General Lewis B. Hershey, director of the Selective Service Training System, will leave his busy desk in Washington to appear as one of the four contributors to the symposium.

It is obvious that mathematics, physics and mechanics are essential for service in the Air Corps, the Signal Corps and the Navy, but what about such a subject as entomology? At first thought it appears to be a field that can be left uncultivated until after the close of the war. To assume that it is not now important would be an error. Perhaps its most obvious practical application is in the domain of public health because many serious diseases, such as malaria and yellow fever, are spread by insects. Within the past fifteen months the association has sold for the use of the Army and Navy about 2,000 copies of its symposium on human malaria, a large part of which is devoted to mosquitoes that transmit malaria and to methods of their control. But entomology is of great importance in quite different ways. For example, it is directly involved in the great problem of protecting growing food crops against insect pests. Acute scarcities of some of the important materials of which insecticides are made present a real threat to our food supply.

Among the subjects involved in problems of importance in prosecuting the war are botany in connection with rubber and food plants, geology as related to minerals, mathematics for artillery and navigation, psychology in questions of morale, engineering in industrial production, medicine in health of armed forces and civilians, agriculture for food, chemistry in the manufacture of products ranging from explosives to vitamins, and practically all the many other fields of science for which the association has sections or affiliated societies that present programs at its meetings. War and the pursuits of peace alike now hang on science. It colors philosophy and religion and all our ways of thinking; it makes interdependent the scholar and the denizen of the jungle. In fact, science has integrated the world, and it now remains for such organizations as the American Association for the Advancement of Science to serve as an efficient integrating agency for science to the advantage of both science and humanity.

F. R. Moulton,
*Permanent Secretary*

## OLIN HALL OF CHEMICAL ENGINEERING AT CORNELL UNIVERSITY

OLIN HALL OF CHEMICAL ENGINEERING, given to Cornell University by Franklin W. Olin, was dedicated in October. It will house the specialized facilities required by the staff and students of the School of Chemical Engineering.

The building, as designed and equipped, reflects both the scope and the training procedure of the course in chemical engineering developed at Cornell under the leadership of Dr. Fred H. Rhoades, Johnson Professor of Industrial Chemistry and director of the School of Chemical Engineering. The curriculum, which leads to the degree of bachelor of chemical engineering, is ten semesters in length. This long period has appeared necessary in order to provide the necessary amount of training in basic chemistry and in plant engineering and then to integrate these into chemical engineering procedures.

As a student progresses in the course, he is required to exert an increasing degree of initiative and resourcefulness. To this end the fifth-year men are required to work on individual projects. Facilities to accommodate such projects take the form of unit laboratories, to each of which four men are assigned and in which the projects may be developed under the guidance of the instructor without disturbance by other students. The group in each unit laboratory is responsible for all that goes on in that laboratory. Each such room is equipped with laboratory desks and the customary supply of electricity, gas, water and air. Each laboratory is also provided with a hood, and there are available connections for drainage and exhaust from special apparatus that may be erected.

In further support of the program for the development of initiative and resourcefulness, there is provided a three-story unit operations laboratory, together with an auxiliary pipe shop, machine shop and wood shop, in which pilot plants may be designed and erected to test under operating conditions the

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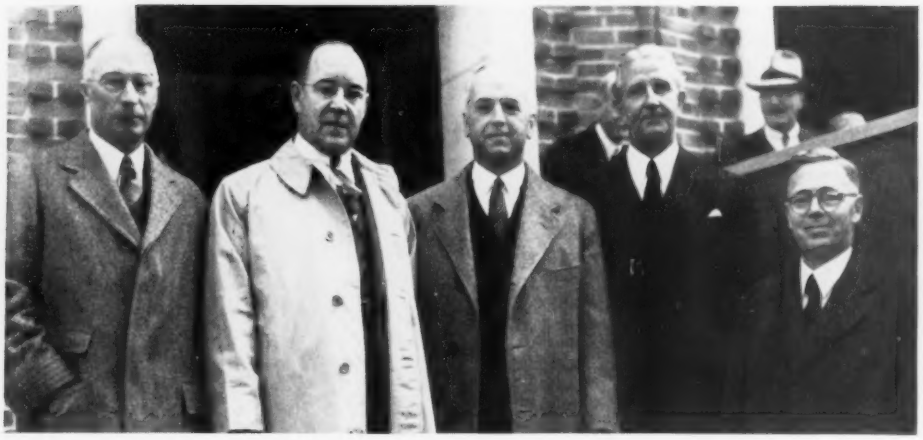

PARTICIPANTS IN THE DEDICATION CEREMONIES OF OLIN HALL

*Left to right:* HOWARD E. BABCOCK, CHAIRMAN OF THE BOARD OF TRUSTEES OF CORNELL UNIVERSITY; JOHN OLIN, SON OF THE DONOR OF THE NEW BUILDING; PRESIDENT E. E. DAY; JOHN L. COLLYER, PRESIDENT OF THE B. F. GOODRICH COMPANY, WHO MADE THE PRINCIPAL ADDRESS; AND DEAN S. C. HOLLISTER OF THE COLLEGE OF ENGINEERING.

plant design developed under the student's project. The laboratory houses large pieces of equipment, such as evaporators, stills, absorption towers and filter presses, upon which the actual operation of pilot plants can be studied to secure accurate examples of performance of similar full-size plants for commercial manufacture. This laboratory also provides facilities for groups of students organized on the foreman-and-squad plan to run tests upon single pieces of specialized plant equipment.

Since Olin Hall is designed to accommodate 450 undergraduates and a proportionate number of graduate students, care has been taken to avoid congestion in the halls between classes. To this end, three of the four lecture rooms, a working library and reading room, three of the five recitation rooms, and the computation room have been placed on the first floor of the main wing, within easy reach of the main entrances. Eyestrain and other discomforts are avoided by constructing the lecture rooms without windows and furnishing artificial illumination at a uniform level. Temperature and ventilation are automatically controlled.

Special laboratories are well-equipped for work in chemical microscopy, metallurgy and metallography. Facilities are provided for the grinding and polishing of specimens. A wide range of equipment is provided for training the student in the necessary photographic techniques employed in these laboratories.

An important detail of construction is the use by the architects, Shreve, Lamb and Harmon, of cinder concrete block for all interior wall surfaces. These surfaces are then spray-painted to obtain the desired color. The effect of the porous texture of these blocks is to provide admirable acoustics throughout the building. Olin Hall is the first of the new group of buildings contemplated for the college of engineering at Cornell University. The entire project is laid out on the same functional basis as the design of Olin Hall.

S. C. HOLLISTER, *Dean*
COLLEGE OF ENGINEERING

## THE POTOMAC RIVER IN FLOOD

On the twelfth of October, 1942, a tropical disturbance moved inland over the North Carolina Coast and dissipated.

A cyclonic circulation, established by this disturbance, persisted until the 17th, with its center over southeastern Virginia. The tropical disturbance carried with it a very deep current of moisture-laden air which extended over the headwaters of the Potomac River. A stagnant anticyclonic circulation over the northeastern United States helped to intensify the pressure gradient over northern Virginia so that persistent easterly winds were forced to rise and release very heavy rains over the windward slopes of the Appalachian Mountains. These rains combined with other convective showers, caused by lifting and convergence of the moist air brought in by the tropical disturbance, to produce a four-day period of record rainfall. Thus the stage was set for the highest flood of record in parts of the Potomac and Rappahannock River basins, the flood waters of the Potomac reaching its peak at Washington, D. C., on the morning of October 17.

The rains were heaviest during the fourteenth to the sixteenth and the maximum precipitations were recorded over the watershed of the Shenandoah River, which flows in a northerly direction to join the main Potomac River at Harpers Ferry, West Virginia, and in the headwaters of the Rappahannock River. Official records of the Weather Bureau indicate that more than 17 inches of rain fell in the vicinity of Front Royal, Virginia, and nearly 19 inches at Big Meadows, Virginia, during the storm period. An unofficial measurement of 27 inches was reported from a point a few miles north of Front Royal.

*U. S. Army Photo*

POTOMAC RIVER AT GREAT FALLS AT THE HEIGHT OF THE FLOOD

The highest stages ever known occurred in the Shenandoah River; at Riverton, Virginia, it is estimated that the river reached a peak of about 46 feet based on the Weather Bureau gage at that point. The waters were too high to allow the gage to be read at the time of the flood peak, but the elevation was determined from flood marks. In the great flood of March, 1936, a crest stage of 37.5 feet was reached on the Riverton gage.

In the history of Potomac River floods, during the period in which records are fairly well known, two floods have had prominence. These were the great floods of June, 1889, and March, 1936, and both were of about the same magnitude. In 1889 the flood in the Potomac was somewhat overshadowed by the much greater disaster at Johnstown, and in 1936 severe floods were even more wide-spread. Then record-breaking floods occurred in the Ohio River headwaters at Pittsburgh, in the Susquehanna River in Pennsylvania and New York, in the Connecticut and other rivers in New England, and in the James River at Richmond.

However, in 1942 the extremely heavy rains were almost entirely confined to northern Virginia, and except for the damaging flood in the Rappahannock River at Fredericksburg, Virginia, and neighboring points, the spotlight was turned on the Potomac and Shenandoah Rivers. The flood waters moved on Washington to produce a higher stage than had ever been recorded. The stage of 17.5 feet above Mean Low Water in the Georgetown channel at the foot of Wisconsin Avenue on October 17, 1942, was a third of a foot higher than the mark set in March, 1936.

Precautions to protect the city against floods had been taken even before 1936 and had been improved since then.

*U. S. Army Photo*

FLOOD SCENE IN POTOMAC VALLEY ABOVE WASHINGTON, D. C.

*Washington Evening Star*

A VIEW OF THE FLOODED STREETS OF BLADENSBURG, MARYLAND

These were mainly in the form of raised embankments and levees and improved channel conditions. However, with the greatly increased industrial and governmental establishments in Washington, with the need for temporary levees in certain instances and with the usual encroachment on the flood plains of rivers by peoples, it was necessary to warn residents and industries of this city and nearby towns that the Potomac River and its tributaries were to overflow their banks in the biggest flood since 1936.

Flood forecasting is founded on two of the older sciences, hydraulics and meteorology. Hydro-meteorologists of the U. S. Weather Bureau forecast river stages and flood crests by a series of computations in which the known quantities are the height of the stream farther up its course, precipitation in the watershed and the river's past performance. Gages at strategic points along the river and its tributaries provide the necessary information on river stages and a network of rainfall stations over the entire watershed furnishes the data on precipitation.

The river gages and the rainfall gages are usually read by a part-time Weather Bureau employe living nearby and the readings are reported by telephone or telegraph to the Weather Bureau office at regular intervals or when requested.

Gages are of several types. The two main classes are the recording and the non-recording. Non-recording river and rain gages are read by observers at designated intervals and these readings form the record. Recording gages automatically measure the rise and fall of the stream, or the fall of precipitation, on a continuous record sheet. The sheets are taken out from time to time by the observer.

Automatic river gages also are used in

*Washington Evening Star*

BARRICADING A STREET IN WASHINGTON AGAINST THE FLOOD

which the recording end at the river's edge measures the stream's rise and fall and transmits the record by leased telephone lines to the receiving end of the instrument in the Weather Bureau office some distance away.

Another type of automatic river gage which was used to great advantage in the present flood is a device whereby signals may be obtained from the gage by telephone indicating the stage of the river in feet and tenths or hundredths. The mechanism which transmits the signal is activated by a float attached to a tape. The float rises and falls with the level of the water in a stilling well corresponding to the stage of the river. The signals transmitted vary in sound or in time interval depending on the stage of the river. The gage house is called as in making an ordinary telephone call. As the telephone rings another automatic device raises the receiver and at the same time the signaling mechanism begins to operate and the signals are heard over the telephone.

Any type of gage is often damaged or put out of commission by severe floods. Even rain gages are sometimes flooded or washed out by high water. In the 1936 flood the automatic recording river gage at Washington failed to function. However, in the present flood, river stages were obtained by telephone, 24 hours of the day and as often as desired, from the gage in Washington and another located about 6 miles above the city. At the same time a pen in each of these gage houses traced out the continuous rise and fall of the stream on a record sheet.

BENNETT SWENSON
U. S. WEATHER BUREAU

## GEOGRAPHY AND TOOTH DECAY

BECAUSE tooth decay is such a common disease, there is a general tendency to believe that all individuals and groups in the population are affected in much the same degree. There is considerable evidence to indicate that such a conclusion is inaccurate.

Significantly less tooth decay is found among groups who reside in certain geographic areas and, therefore, are exposed to specific environmental influences characteristic of these regions, than is found among other groups living under what are, apparently, much less favorable conditions. The record of physical examinations for military service outlines this situation.

During the last World War, data were collected from draftees which show a wide sectional difference in the rate per thousand of men rejected for "defective and deficient" teeth. It is true that diseases other than tooth decay would contribute to the conditions causing this type of "unfitness." Yet it is believed that among the particular age groups involved, the effects of dental diseases other than tooth decay upon the rates would be so minor that they may be disregarded. "Defective and deficient" teeth stood eighth among the thirty-seven items which were listed as leading to rejection for physical unfitness. Of men from the forty-eight states and the District of Columbia, the mean rate was 24.2 per thousand men examined. The distribution about this mean ranged between 2.90 for Arkansas and 102.85 for Vermont. The New England states, as a unit, outranked all others, while the states of the South and Southwest were consistently low on the scale.

In the Civil War, the condition described as "missing teeth" contributed significantly to physical unfitness among the men who were drafted from the northern states during 1863 and 1864. The rejection rate for dental defects, 20.49 per 1,000 examined, stood fourth in magnitude among the sixteen items listed as leading to rejection. It was noted at that time that there were marked differences between various states in the number of men rejected for this defect. The men of New England, when compared with those of the other states, were found to have the poorest teeth. Among the states contributing to the drafts of the two periods, there is striking agreement in the order in which the rates fall when listed according to magnitude.

Sufficient data from the present draft are not yet available to allow a reliable conclusion to be drawn regarding the current situation, but preliminary reports indicate there will be a comparable distribution of rejection for "deficient and defective" teeth.

The dental defects which cause men to be physically unsuited for military service are not likely to have started their development in the adult, but in the youth. Extensive surveys among children of school age indicate a relationship of caries attack to geographic location that is similar to that obtained from war records. For example, among boys having a mean age of 13, residing in cities of over 100,000 in Florida, Virginia and Massachusetts, the mean number of caries-attacked permanent teeth per child was found to be 3.1, 4.2 and 5.7, respectively. Similar differences have been noted among children of other states.

BION R. EAST

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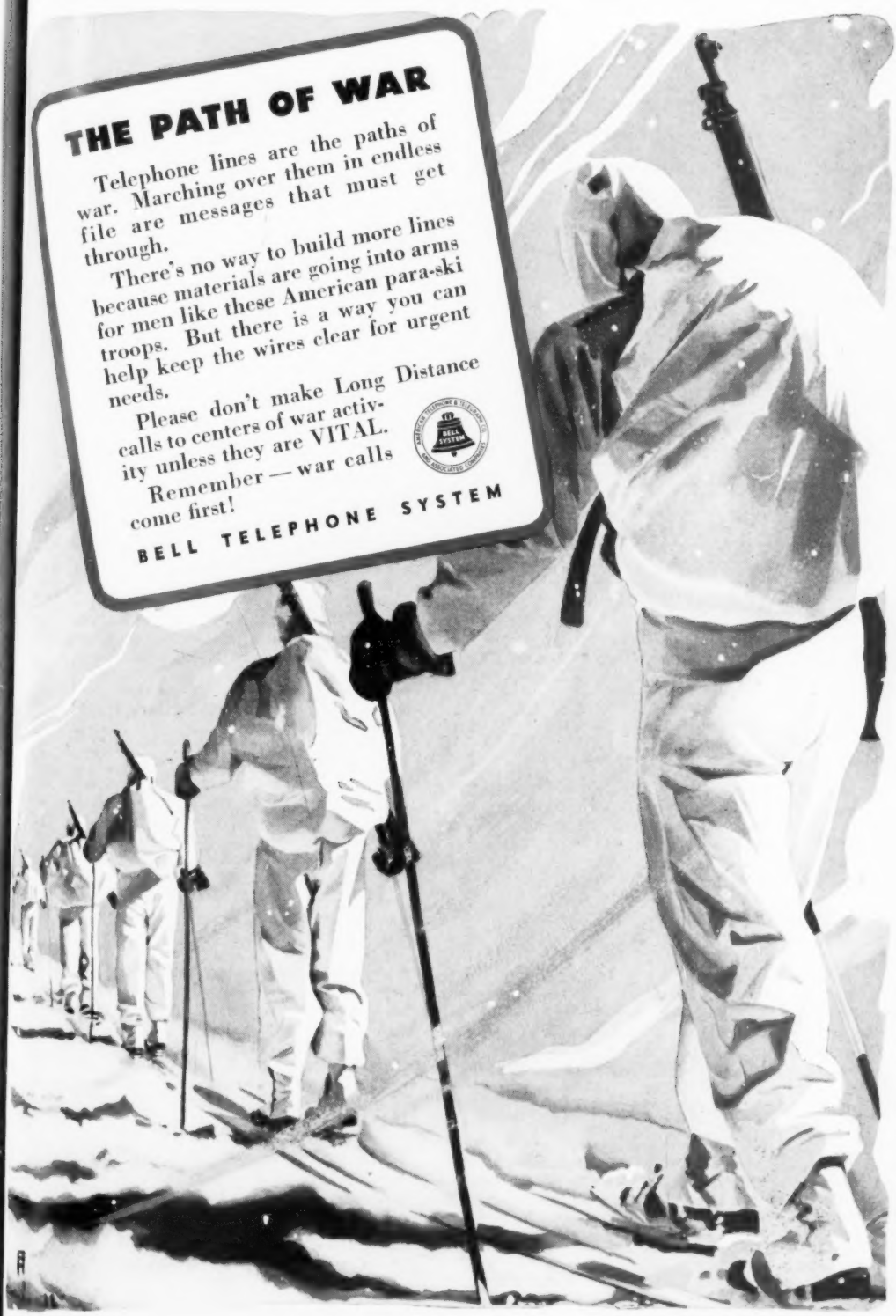
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## RECENT BOOKS OF SCIENTIFIC INTEREST

**The Vertebrate Eye.** G. L. WALLS. Illustrated. xiv + 785 pp. $6.50. August, 1942. Cranbrook Institute of Science.

The vertebrate eye and its adaptive radiation are discussed in three main sections: the fundamental background information, the environmental reasons for evolutionary changes, and the history of the eye traced from the lowest living vertebrates to the highest.

**The Dictionary of Philosophy.** Ed. by D. D. RUNES. 343 pp. $6.00. 1942. Philosophical Library.

The aim of this dictionary is to provide teachers, students and laymen interested in philosophy with correct definitions and descriptions of the philosophical terms throughout the range of philosophical thought. In the volume are represented all the branches as well as schools of ancient, medieval and modern philosophy.

**On Growth and Form.** D. W. THOMPSON. Illustrated. 1116 pp. $12.50. August, 1942. Macmillan (Cambridge).

This volume covers biological problems of growth and form, and form and function, in their relation to physical principles and mathematical laws. The physics and mathematics used are elementary, but advanced enough to throw light on fundamental biological problems.

**Climate and Man.** Illustrated. xii + 1243 pp. $1.75. 1941. U. S. Government.

Designed to aid farmers, a large part of this volume is devoted to a detailed discussion of the relation of climate and weather to crops. The second half of the book contains maps and tables of data on climate in all parts of the United States intended to assist farm operations in agricultural communities.

**The Social Life of a Modern Community.** W. L. WARNER and P. S. LUNT. Illustrated. xx + 46[illegible] pp. $4.00. 1941. Yale.

The authors write of a class hierarchy in which the people of the American town are distributed through six social strata, with most of the social behavior influenced by class factors. The volume is the first in the six-volume "Yankee City Series."

**Motivation and Visual Factors.** BENDER and others. xix + 367 pp. 1942. Dartmouth.

The authors of this volume, through the study of psycho-portraits based upon tests, interviews, and autobiography, have arrived at the conclusion that visual factors, even extreme deviations, do not in and of themselves cause maladjustment. The report has been drawn from the study of twenty college students.

**Benjamin Franklin's Experiments.** Ed. by I. BERNARD COHEN. Illustrated. xv + 453 pp. $4.00. Harvard.

This work includes a new edition of Franklin's Experiments and Observations on Electricity together with a four-chapter introduction by Mr. Cohen the purpose of which is to prepare a scientific and biographical background for the presentation of Franklin's papers.

**The Pigeon.** W. M. LEVI. Illustrated. xxxii + 512 pp. $10.00. 1941. R. S. Bryan.

The author presents for those who, like himself, find relaxation and stimulation in the hobby of pigeon-raising, a book which covers such topics as the relationship of pigeon and man; breeding and care, anatomy, physiology, genetical variations, behavior, etc. Over 600 pictures and diagrams illustrate the text.

***Books previously announced will be given space six times on this page for $12.00***

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96 Illus., 204 Pages; $2.50

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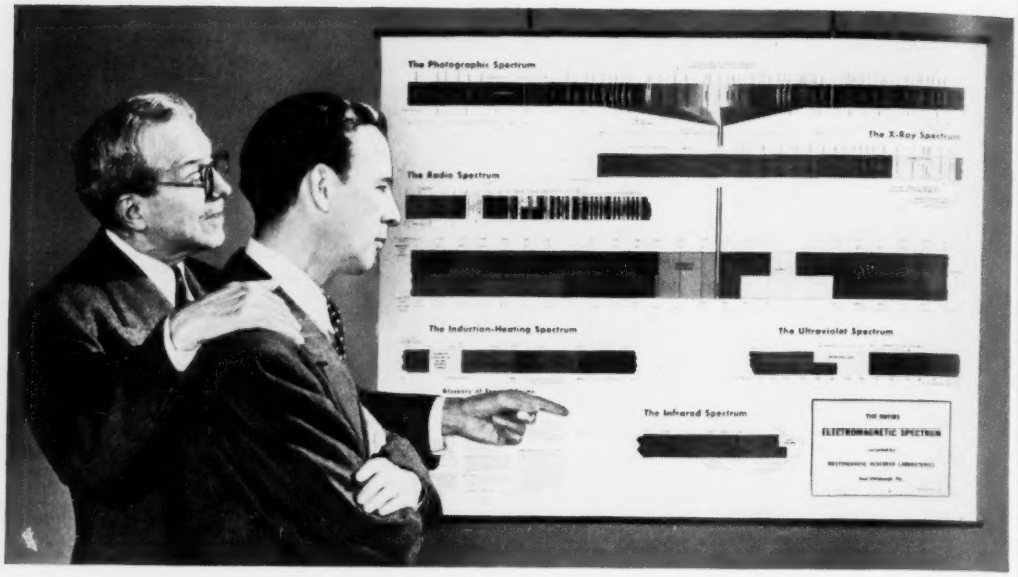


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